2013

PSY1 Stem Psychrometer Manual

Mike Dixon - University of Guelph

Alec Downey – ICT International

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1 Contents

2 System Requirements

2.1 CPU Processor:

The ICT Instrument software does not require large processing power.

For example it is compatible with NetBooks.

Minimum Recommended Processor Capacity:

Intel Atom Processors with a CPU N270 @ 1.66 GHz and 1GB RAM or higher.

2.2 Software:

The ICT Instrument software is compatible with the following Windows Operating Systems:

a. Windows XP
b. Windows Vista
c. Windows 7
d. Windows 8
e. Windows Virtual OS run from a Mac computer

2.3 Screen Resolution:

The ICT Instrument software is written to a fixed screen resolution of 857 x 660 dpi (it does not Auto Resize) and works best on current model laptops that have a screen size of 11.6” or larger and a default screen resolution of 1366 x 768 (the vertical height of 768 being most important otherwise you can't see the bottom of the software).

This means on small netbook’s and some old laptops the bottom 5 or 10% of the screen is cut off or obscured from view. This can significantly limit software functionality.

The only netbook ICT is aware of that does support the ICT Software in full window display, is the ACER Aspire One netbook. It has an 11.6" screen with resolution 1366 x 768 dpi. This is the smallest netbook that supports the software as it offers a standard, full laptop screen resolution (1366 x 768). The advantage of netbooks are the lightweight (and often Solid State Drives, SSD) which make them ideal for field use, and in fact much better suited than a standard laptop. They are also very cheap.

The only solution for netbooks with a smaller screen size is to adjust your Display Properties Settings (right click on your desktop and choose properties) to 1366 x 768 or higher. NOTE: you will need to close the Instrument software first before doing this to ensure the window displays correctly on the screen. Most netbooks or laptops will not save this setting so you will need to repeat this procedure every time you start your computer.

3 Recommended Reading

a. Dixon M.A., & Tyree M.T. 1984. A new stem hygrometer, corrected for temperature gradients and calibrated against the pressure bomb. *Plant Cell & Environment* **7**: 693-697.

b. Dixon M.A., & Johnson R.W. 1993. Interpretation of the dynamics of plant water potential. In: *Water Transport in Plants under Climatic Stress*. Edited by M. Borghetti, J. Grace and A. Raschi. Proceeding of an International Workshop held in Vallombrosa, Firenze, Italy.

c. Shackle, K. 1984. Theoretical and experimental errors for in-situ measurements of plant water potential. *Journal of Plant Physiology* **75**: 766-772.

d. Tyree, Melvin T, Fiscus, Edwin L, Wullschleger S.D & Dixon M.A 1986. Detection of Xylem Cavitation in Corn under Field Conditions. *Plant Physiology* **82**:597-599

e. Johnson, R.W, Dixon, M.A, and Lee, D.R. 1992. Water relations of the Tomato during fruit growth. *Plant Cell & Environment* **15**: 947-953.

f. Edwards D. R, and Dixon, M.A. 1995. Mechanisms of drought response in *Thuja occidentalis* L. I. Water stress conditioning and osmotic adjustment. *Tree Physiology* **15:** 121-127

g. Edwards D. R, and Dixon, M.A. 1995. Mechanisms of drought response in *Thuja occidentalis* L. II. Post-conditioning water stress and stress relief. *Tree Physiology* **15:** 129-133

h. Chamberlain, C.P, Stasiak M.A. and Dixon M.A. 2003. Response of Plant Water Status to Reduced Atmospheric Pressure. *SAE International* 2003-01-2677

i. Robinson, S, Dixon M. A, and Zheng Y. 2007. Vascular blockage in cut roses in a suspension of *Pseudomonas Fluorescens. Journal of Horticultural Science & Biotechnology* **82** (5) 808–814

j. FISHER, Rosie, A., WILLIAMS, Matthew, LOBO DO VALE, Raquel, LOLA DA COSTA, Antonio & MEIR, Patrick 2006. Evidence from Amazonian forests is consistent with isohydric control of leaf water potential.*Plant Cell & Environment* **29**: 151-165

k. Lang, A.R.G, Osmotic Coefficients and Water Potentials of Sodium Chloride Solutions from 0 to 40°C 1967. *Australian Journal of Chemistry*, **20**, 2017-23

4 Quick Start Guide

NOTE $_1$ - This manual includes hyperlinked instructional videos to complement each major section for both practical operation and software function. These videos are located on the ICT YouTube site www.ictinternational.com/videos.html you will require internet access to view the videos whilst reading the manual. Alternatively, the videos are supplied on a DVD together with the manual when you purchased the PSY1 Stem Psychrometer. Videos on DVD can be supplied by ICT upon request.

WARNING $_1$ – The Thermocouples of the Stem Psychrometer Chamber are made from very fine wire only 25 µm in diameter. NOTE: Human hair is, on average 100 µm thick. You will require a 20 x dissection microscope to view the thermocouples. You cannot see them or manipulate their position with the naked eye. Thermocouples are easily broken if handled incorrectly by unprepared operators. Please READ section 8 - Handling the Psychrometer and WATCH **VIDEO** $_1$ **SP13** Adjustment before removing the chamber's calibration lid.

4.1 Charge the PSY1 Internal Battery

The PSY1 is a self-contained instrument that incorporates a lithium polymer battery. Before using the instrument, this battery MUST be charged. To choose from a range of charging options see section 7 – Charging - Powering the Instrument.

4.2 Clean the Psychrometer Chamber

The Stem Psychrometer consists of two very small welded thermocouples using very fine wire only 25 µm in diameter. This makes the sensor very sensitive to measuring water potential but equally as sensitive to dirt and even mild oxidation. It is recommended that before starting any measurements you clean the thermocouples following the instructions in section 10 - Cleaning the Psychrometer and watch VIDEO $_2$ SP12 Cleaning.

4.3 Install the PSY1 Software & USB Driver

Insert the supplied CD into the computer. The CD will auto-run to present a menu. Choose install software; see section 11 - Software & USB Driver Installation for details.

4.4 Turn the Instrument On

The PSY1 can either be turned on manually by pressing the power button (see section 12 - Turn the Instrument On) or automatically by connecting an external power supply (see section 7 – Charging - Powering the Instrument).

4.5 Connect to the Instrument

Connect the USB cable to the instrument. The PSY1 will automatically be detected by the computer as with any USB device. Double click the PSY icon on the desk top to open the software and click the icon "Connect to PSY", then search for and select the named instrument from the connections Window. See section 13 – Communications - Connect to the Instrument for details.

4.6 Set the Measurement Protocols

Each installation will be different if only slightly. For this reason measurement protocols such as the Sensor Calibration slope and intercept, Peltier Cooling Pulse options or Chamber Heating schedule should be set before deploying the instrument and checked periodically throughout the experiment. See section 14 - Measurement Protocols for details.

4.7 Calibrate the Sensor

The Stem Psychrometer MUST BE calibrated before each measurement. The calibration employs a 6 point measurement protocol using known NaCl molality solutions. Watch **VIDEO** $_3$ SP10 -Calibration Procedure. The calibration must be done under isothermal conditions (Watch **VIDEO** $_4$ SP09 Calibration Chamber**)** at a controlled temperature of 25 ° C to generate a specific slope and intercept that characterises the specific response of the individual thermocouples. A detailed calibration function is provided within the PSY1 software that can be used to generate and automatically load your new calibration into the PSY1 firmware. See section 15 – Calibration Procedure for details and watch **VIDEO** $_5$ SP 14 Calibration The calibration is applied and tracked via the four-digit serial number of the psychrometer chamber and will remain in the instrument in non-volatile RAM until changed by the user. This number must be manually entered into the instrument firmware. See sub section 17.1 –Instrument Information in section 17 - Instrument Setup & Configuration.

4.8 Install the Sensor

Care must be taken to prepare the site for installation. See section 16 – Installation Procedure for details and watch VIDEO $_6$. SP05 Installation and **VIDEO** $_7$ **SP04 Installation Preparation** and VIDEO$_8$ SP03 Installation Issues. **NOTE:** Any living tissue or cells left behind will grow into the chamber and cause terminal damage to the thermocouples of the psychrometer chamber and need to be returned to ICT International for repair. Please Request an RMA# before returning anything to ICT.

4.9 Set the Logging Interval

The stem psychrometer has a minimum temporal logging resolution of 10 minutes. This limit is imposed by the thermodynamics of the Psychrometric principle. The stem psychrometer chamber must be allowed time to dissipate all thermal gradients and re-equilibrate with the stem prior to commencing a new measurement. See section 18 - Measurement Control for details

4.10 Download Data

Data can be downloaded in a number of ways. The simplest is to click the green Download Data icon on the main window under Instrument Information section 17.1. If a data file exists on the MicroSD card then a Windows Explorer window automatically loads providing a choice of directories to save the data file to. Alternatively, the MicroSD card can be physically removed and read by a computer. See section 20 - Downloading Data for details.

4.11 Analyse Data

Data is saved in a CSV file and can be analysed using your preferred spread sheet or statistics software. An upgrade for SFT Sap Flow Tool Software is being written to enable analysis of stem water potential data from the PSY1 that will facilitate direct comparison with measured sap flow data where applicable. Contact ICT International for more information.

5 Description

The PSY1 stem psychrometer consists of: a psyhcrometer chamber; calibration disk holder and; an integrated, standalone data logger with Windows Graphical User Interface (GUI) software for instrument configuration and data downloading. A solar panel can be directly connected to the non-polarised charging ports to trickle charge the internal battery for continuous field operation.

Photo 1 PSY1 Stem Psychrometer complete

5.1 Stem Psychrometer Chamber

The psychrometer chamber is made of chrome plated brass to achieve a large stable thermal mass. Two welded Chromel-Copper, and one Constantan–Copper thermocouple are housed within the chamber. The measurement is performed by passing a Peltier cooling pulse through the C or Chamber Thermocouple to generate a Psychrometric Wet Bulb Depression (WBD). This Wet Bulb depression is automatically corrected for temperature and processed using the slope and intercept of the specific calibration for the stem psychrometer to yield Stem Water Potential (MPa)

Photo 2 PSY1 Stem Psychrometer chamber

5.2 Calibration:

ICT International does not supply the stem psychrometer with a factory calibration.

Calibration of the instrument can be performed by the user. A calibration disk holder, a comprehensive software calibration function and instructions are included.

However, ICT does offer a calibration service for an additional fee. Please contact ICT for more information and a formal quotation.

5.3 Clamping:

A clamping device is required to attach the psychrometer to a plant stem. Two sizes of clamps are available:

a. Small Clamp (PSY-SC) for stem sizes up to 25 mm diameter and;
b. Large Clamp (PSY-LC) for stem sizes between 25 to 50 mm in diameter.

Use of the stem psychrometer with larger stem sizes will require a customised clamping mechanism, and these are explained in section 17 - Installation under sub section 17.2 Large Diameter Stems. However, these two basic clamp sizes should be adequate for most applications. This is because the stem water potential is an absolute measure of the integrated water potential within the plant at the point of measurement. Whilst gradients will exist vertically in the plant, stem water potential measured on a lateral branch adjacent to the stem (which may be small enough to attach a psychrometer using one of the two standard clamp sizes) will be directly representative of the stem water potential of the adjacent main stem or trunk of the plant.

5.4 Measurement Options:

The PSY1 Stem Psychrometer can then be used as a psychrometer for

(1) In-situ water potential on the stem
(2) In-situ water potential on the leaf
(3) Water potential on excised stem tissue
(4) Water potential on excised leaf tissue
(5) Or as an osmometer for direct measurement of osmotic potential

5.5 Measurement of Stem Water Potential:

The stem psychrometer measures the psychrometric wet bulb depression and ultimately the stem water potential of the plant and can be used in-situ on the stem or leaf of a plant or on detached stems or leaves for dry down experiments or pressure volume curves.

5.6 Measurement of Leaf Water Potential:

Stem water potential measurements can also be performed on a prepared and insulated leaf in-situ on the plant. The leaf must be “bagged” or insulated from direct solar radiation and thermal gradients. This of course shuts down photosynthesis meaning the water potential is no longer that as seen by the specific leaf, rather the leaf effectively becomes a manometer to the plant. The leaf is still hydraulically connected to the plant hence the stem water potential and that of the leaf come to hydraulic equilibrium. This technique has been successfully used on a range of plant types, *Shackel, K. Theoretical and Experimental errors for In-situ Measurements of Plant Water Potential, Plant Physiology, Vol. 75 1984* Please contact ICT for more information.

5.7 Measurement of Osmotic Potential:

Using the calibration lid the PSY1 can also be used to measure (destructively) osmotic potential (MPa). An abraded leaf disc or filter paper disc (saturated with extracted sap exudates from a suitably prepared sample using a freezing and physical disruption protocol to separate the symplastic fluid from the cells of the leaf), are placed in the calibration lid. To achieve good thermal insulation from ambient thermal gradients (that cause noise and measurement error), the stem psychrometer chamber must be housed inside the Osmotic Potential Insulator (PSY-OPI). Then, using the PSY1 software a manual measurement can be made or repeated measurements made at a defined logging interval.

5.8 PSY1 Stem Psychrometer Meter:

The PSY1 is a highly accurate, high precision microvolt meter that has been custom designed to specifically measure stem water potential. It features an integrated stand-alone data logger consisting of a 24-bit resolution preamplifier and microprocessor with integrated A to D converter that outputs and logs processed data in calibrated engineering units (MPa).

Photo 3 PSY1 Meter

5.8.1 Water Proofing:

The custom designed enclosure of the PSY1 has an IP65 rating. It can be submerged under 10 m depth of water (equivalent to approx. 0.1 MPa or 1 atmosphere) without water ingress. This protection is across all electrical circuitry preventing water damage that is common among other field equipment.

Water proofing is achieved through a unique physically separated, but electrically linked dual chamber enclosure design. This ensures that the internal circuitry and battery can be electrically linked and charged from an external power supply without providing any physical pathway for water ingress. For this reason it is important not to open the enclosure because opening the enclosure will void the warranty and water proofing guarantee.

NOTE 2 - there is no reason to open the enclosure as ICT have provided water proofed access to all necessary interfaces of the instrument such as USB communication port, Micro SD card and power switch.

WARNING 2 – Water proofing cannot be achieved if the communication port cover is left unscrewed. Water entry via this port WILL cause damage and is not covered under warranty.

5.8.2 Power Management:

The instrument has its own internal 4.2V (800 mA) lithium-polymer battery. It features: a non-polarised power circuit; internal voltage regulation; a voltage inverter to drive a 12V heater inside the psychrometer chamber, if heating the chamber to prevent condensation is necessary; a regulated current generator to provide the Peltier cooling current; and optical isolation and lightening protection.

5.8.3 External power:

External power can be supplied with a DC voltage supply from either, a 10 W solar panel or mains powered 12V DC plug pack see Charging – Powering the Instrument for specific details and charging options.

5.8.4 Tools:

No custom tools are required for connection of power supply or instruments. External power is inserted through the non-polarised power-bus ports of the instrument utilising a unique bare wire, push fit connection mechanism. The stem psychrometer is fitted with a water proof Bulgin connector that screws to the instrument.

5.8.5 Power Fail Safe Mode:

In the event that power is lost, due to adverse radiation levels such as extended monsoonal cloudy conditions the logger will enter a hibernation mode, much like a laptop. However, as soon as the battery is recharged the whole system will reactivate and recommence logging at the preconfigured intervals without human intervention. Data will not have been recorded for the period that the

system was in hibernation, but no data collected prior to hibernation will be lost. It is permanently stored in non-volatile memory on the MicroSD card.

5.8.6 Lightning Protection:

Lightning protection is achieved through the design of optical isolation, physical interrupts and barriers into the circuit boards of the instrument. These prevent electrical discharge from lightning running throughout the circuit and destroying the instrument. This is an important protection feature against electrical discharge, but it will not prevent damage and complete destruction from a direct lightning strike on the instrument. Nothing can.

5.8.7 Data Storage & Memory:

Data is stored to a 2GB MicroSD card (standard). Larger capacity up to 16GB Micro SD cards can be used if required. All SD card memory formats are supported including SD, SDHC and SDXC.

The memory capacity of the standard 2GB MicroSD card is approximately 443 years for the primary data file when all parameters are logged at a 10 minute temporal interval (the maximum frequency).

5.8.8 Communication:

Is via a direct USB cable interface to a computer. No RS232 serial to USB adapters are required. Alternatively, every instrument includes a 2.4 GHz transceiver for wireless two way communication. This feature is standard in all PSY1 instruments manufactured after April 2012 and does not require activation or upgrading of the instrument. Wireless communications up to a distance of 250 m (line of sight) is achieved when used with an MCC1 radio modem.

5.8.9 Software & Firmware:

Software and firmware updates are automatically available via the ICT web site www.ictinternational.com/download.html . Every time you run the software and or the instrument within internet access the web site is automatically checked for possible updates. If an update is available you are given the option to down load and install the update. Firmware within the microprocessor of the instrument is automatically updated via the USB Boot Strap Loading function. The process takes less than 10 minutes and ensures your system is updated with the latest functionality and features.

5.8.10 Operating Temperature Range:

Maximum operating range is between 80°C to -40°C. A minimum temperature of -40 ° C is possible due to the incorporation of heaters built under the microprocessor chips to warm them to -20 ° C which is the minimum international standard operating temperature for silicon chips and microprocessors to operate at.

NOTE $_3$ - whilst the instrument can operate at these extremes it is unlikely that the plant will.

6 Theory

6.1 Stem Water Potential

Total water potential is the measure of the plants ability to interact with the environment. It consists of four basic components

$$\Psi = Tp - \Pi - T - g \quad \textbf{Equation 1}$$

Where:
Ψ= Total Water Potential
Tp = Turgor Pressure
Π= Osmotic Potential
T= Matric Potential
G = Gravity

The PSY1 Stem Psychrometer is designed to measure water potential with due consideration of ambient temperature and temperature gradients.

6.1.1 Turgor pressure

Is the outward pressure that occurs in a plant cell when the cytoplasm and vacuoles, or membrane bound tissues, fill with water and the cell membrane pushes against the cell wall. The more water within the cell wall the greater the osmotic pressure. Turgor pressure and osmotic potential typically dominate the total water potential of the plant and form the basis of the measurement made by the stem Psychrometer.

6.1.2 Osmotic potential

Osmotic potential is the result of dissolved solutes in membrane bounded tissues of a plant. It is possible to measure this component of total water potential independently on samples from frozen or crushed plant tissue, usually leaves. This is covered in more detail in section Osmotic Potential.

6.1.3 Matric Potential

Matric potential is defined as the energy required to extract water from a porous medium to overcome capillary and absorptive forces and is usually overwhelmed by osmotic potential and turgor pressure as a component of total water potential.

6.1.4 Gravity

In most plants gravity has a negligible effect, but in trees of suitable height such as Redwood (*Sequoiadendron giganteum*) gravity can have a significant affect as demonstrated by figure 1 below in which the PSY1 measured stem water potential at 88m above ground level at the top of a 91 m Redwood tree. The effect of gravity is shown by the night time recovery in stem water potential being offset by approx -0.90 MPa due to the contribution of gravity being equal to approx 101.9m head pressure / MPa.

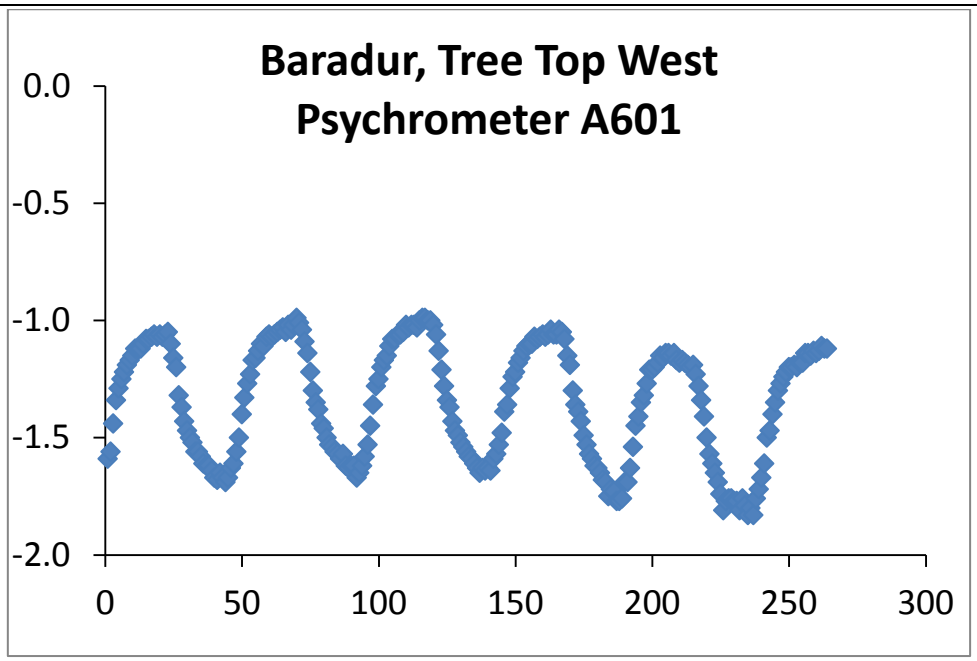


Figure 1 - 5 daily cycles of water potential measured with ICT psychrometer on a branch at about 88 meter height in a 91 meter tall *Sequoiadendron giganteum* At Whitaker's Forest, California during the period Aug. 13 – Aug. 17, 2010. Unpublished Data - Courtesy George Koch Northern Arizona University

6.2 Psychrometric measurement

Each measured parameter in the psychrometric equation is directly measured by the PSY1 Stem Psychrometer. The stem psychrometer is constructed of chromium plated brass to provide a large heat sink for thermal stability during the psychrometric measurement.

NOTE 4: the ambient temperature of the PSY1 can fluctuate within the normal range of diurnal cycles without affecting the measured water potential. However, the temperature within the chamber MUST remain stable throughout the duration of the 20 second measurement period. Rapid temperature changes of even 0.1 °C from the start of the measurement to the end of the measurement will cause noise and errors in the measurement of water potential. To ensure a stable thermal environment the Psychrometer chamber MUST be wrapped in an insulating material that dampens the ambient thermal environment.

The chamber houses two chromel/constantan thermocouples in series; one located in the chamber air (Thermocouple-C) and the second, extending above the chamber well to contact the sample surface (Thermocouple-S). The differential output from these two junctions (ΔT) is a measure of the temperature gradient between the sample (Thermocouple-S) and the measuring junction (Thermocouple-C) and allows the correction of the measurement of water potential for the influence of this gradient.

The PSY1 generates a Peltier cooling pulse (of user definable duration, but typically 10 second), to cool Thermocouple-C sufficiently to condense water on the thermocouple Watch **Video 9** Principle of Operation for a visual example of this process.

The microvolt output of the Thermocouple-C is recorded at a sampling frequency of 10 Hz or 10 times per second. A Psychrometric (Wet-Bulb) depression is read at six (6) seconds after the end of cooling and automatically corrected for any measured temperature gradient between the Thermocouple-C and Thermocouple-S. Finally, these data are automatically processed using the Stem Psychrometer equation applying the chamber specific calibration to yield the precise measurement of the sample's water potential.

A copper/constantan thermocouple is embedded in the chamber body to allow measurement of chamber temperature. This temperature value is recorded by the PSY1 and used to automatically correct the reading to 25 °C, an arbitrary standard reference for water potential measurements.

The stem psychrometer provides the means to measure in-situ water potential over a wide range (–0.01 Mpa to -10 Mpa) with accuracy and repeatability. However, certain precautions (as detailed in the following sections) must be adhered to if meaningful results are to be achieved.

Video 10 presented by Prof. Mike Dixon is a concise explanation of the Stem Psychrometer Theory. Including; the theoretical principle employed by the PSY1 Stem Psychrometer to measure stem water potential; the chamber design; nomenclature used to describe the internal components of the chamber; and the measurement procedure.

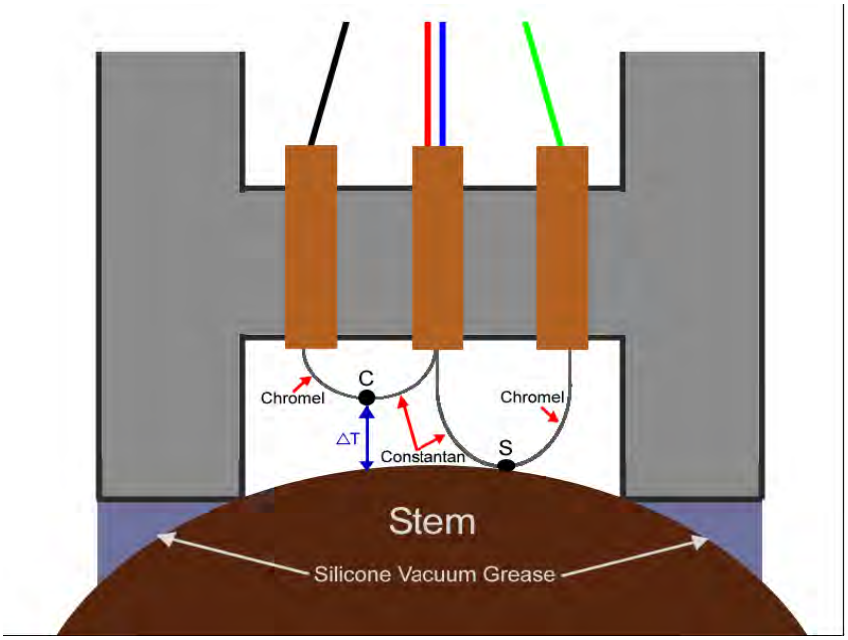
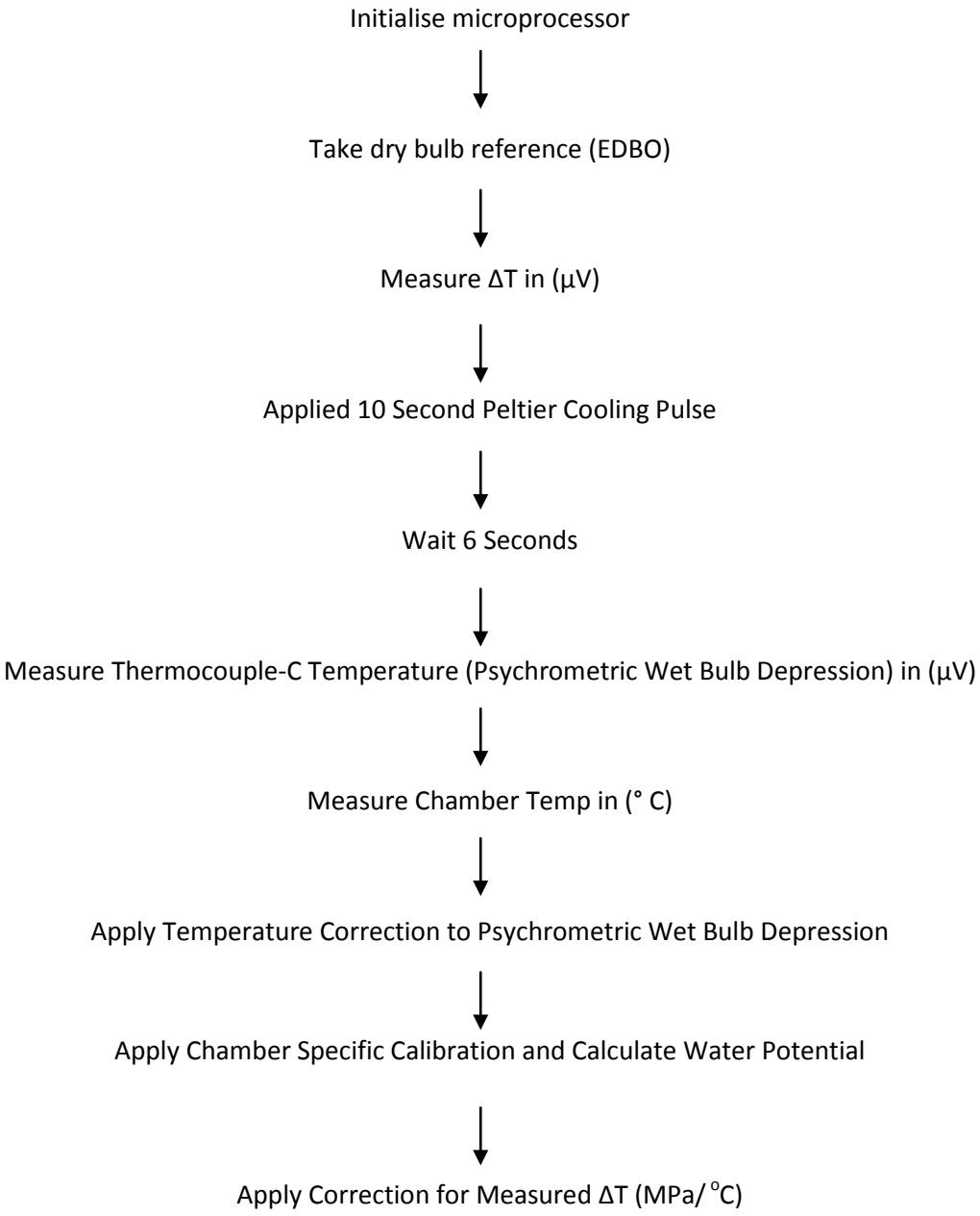


Figure 2 **PSY1 Stem Psychrometer principle schematic**

6.3 Psychrometric measurement protocol



The microprocessor begins a water potential measurement by measuring dry bulb reference or Electronic Dry Bulb Offset (EDBO) and appointing it a value of zero. The difference in temperature of the two chromel-constantan thermocouples (C and S - chamber air and sample respectively) is measured. This represents the temperature gradient between the sample and the measuring junction and is converted to ^{o}C by dividing the reading by 61 (the temperature coefficient of a chromel-constatan thermocouple). It is then multiplied by the correction factor. If, for example, the chamber temperature (i.e. ambient temp.) is 20 ^{o}C, then the correction factor is 8.38 MPa/ ^{o}C. You now have a measure of the error in the apparent measured water potential as a result of the temperature gradient between the tissue and the measuring junction. The water potential is then automatically measured in the psychrometric mode, applying necessary temperature correction.

6.4 Psychrometric equation:

A Psychrometric Wet Bulb Depression (WBD) is measured when a Peltier cooling current condenses water from the atmosphere of the chamber which subsequently evaporates and cools the thermocouple junction. The raw Psychrometric Wet Bulb Depression is corrected for ambient temperature using an empirically derived algorithm. It is then converted to water potential with a calibration slope and intercept derived for the instrument from a six point calibration protocol using solutions of known solute potential (Molality). Finally, a correction for ΔT, or the temperature gradient between the tissue and the measuring junction is applied.

$$\Psi = ((((WBD/((C_1 * T_C) + C_2)) - CI)/-CS) + (\Delta T / k * CF)) \quad \textbf{Equation 2}$$

Where:

Ψ = Corrected Water Potential

C_1 = Empirically derived temperature correction Constant

C_2 = Empirically derived temperature correction Constant

CI = Calibration Intercept

CS = Calibration Slope

WBD = (Psychrometric) Wet Bulb Depression (µV)

T_C = Chamber Temperature (°C)

ΔT = Measured temperature difference between Thermocouple-C and Thermocouple-S (µV)

k = Chromel Constantan Thermocouple output /°C

$CF_{\Delta T}$ = Correction for ΔT - MPa/°C

6.4.1 Psychrometric Wet Bulb Depression

The Psychrometric Wet Bulb Depression is the temperature to which the Thermocouple-C is cooled when water condensed from the chamber air is allowed to evaporate. The Psychrometric Plateau representing the wet bulb depression is systematically determined by pausing for an empirically determined period (6 sec) following the termination of the Peltier cooling. Once all the condensed water has evaporated the temperature of the thermocouple returns to that of the bulk chamber represented by zero (i.e. No difference between the thermocouple and bulk chamber) (Fig 3)

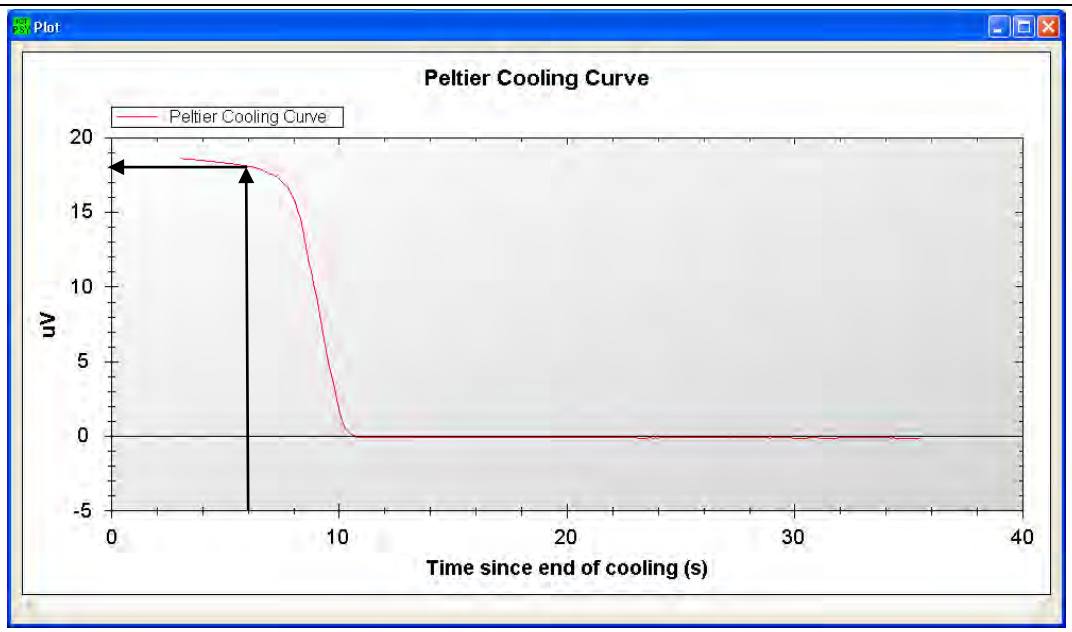


Figure 3 the Psychrometric Wet Bulb Depression is measured on the Psychrometric plateau at exactly 6 seconds after the end of Peltier cooling.

6.4.2 Chamber Temperature

Chamber temperature is important as this is the ambient temperature at which the psychrometric Wet Bulb Depression was measured. It is used in the temperature correction of the raw psychrometric Wet Bulb depression as well as to determine the correction factor for ΔT based upon the conditions under which that measurement was made.

6.4.3 Delta-T (ΔT)

Delta-T is the difference in temperature between the air within the atmosphere of the chamber and the adjacent plant tissue. The temperature of both the chamber air (Thermocouple-C) and the plant tissue (Thermocouple-S) are directly measured to determine ΔT. In an isothermal state this value will be zero. However, in field measurements it is unreasonable to expect that this value will actually be zero, and even small differences in temperature between the two can have a significant effect.

6.5 Psychrometric error

Accuracy of the stem psychrometer at the wet end of the spectrum, around zero (0MPa) is a limitation of the physics of the Psychrometric principle. Where there is little to no drying force, it is difficult to convert liquid water back into vapour phase, and condensation within the chamber is always imminent.

Around zero (0MPa) the error is significantly greater than at water potentials of - 0.5 MPa or lower. As soon as there is a drying force acting upon the thermocouples within the chamber to drive evaporation, the error dissipates rapidly and the accuracy improves. Small positives of +0.1 to +0.2 MPa (whilst not theoretically possible to be measured using psychrometry) are not of serious concern, especially when you see good diurnal rhythms, and can be ignored as mathematical artefacts. A positive offset is also not applicable across the whole data set because the error is dissipated very quickly once a drying force is generated as you extend beyond the very wet water potential range.

NOTE 5 In the majority of applications the wet end of the water potential spectrum below -0.5 MPa is of only moderate interest as most plants do not exhibit water stress at these levels. The majority of water potential and water relations research is conducted when plants are under stress at values between -0.5 MPa to -2.5 MPa and greater for some arid plants. At water potentials of this range a strong drying force exists and accuracy of a calibrated Stem Psychrometer is very reliable.

6.6 Equilibration Time

The stem psychrometer exhibits rapid vapour pressure equilibration. However, chamber temperature gradients, as a result of handling the instrument or ambient fluctuations, generally require more time to dissipate.

Calibration procedures require handling the instrument and usually 15 to 30 minutes are required to re-establish thermal stability under controlled temperature conditions.

Following installation on a stem, significant thermal gradients are usually apparent. Furthermore, disruption of local tissue water potential is likely to have occurred. For these reasons, some hours (2 to 4) should be allowed between the time of installation and the first reading. Using the “Live” mode function you can “watch” in real time the thermal equilibrium occur as the ΔT and Thermocouple-C values are displayed on screen. These data can also be logged to a .csv data file for post processing and analysis.

Provided adequate thermal insulation or temperature control of the installation has been employed, subsequent equilibration to even rapid tissue water potential changes will be dependent only on vapour pressure equilibration. The stem psychrometer exhibits favourable vapour pressure equilibration characteristics due to the absence of significant resistances to vapour exchange (eg. cuticular resistance) between the sample and chamber well.

6.7 Zero Offsets:

On occasion you will find variable zero offsets, especially when operating the psychrometers on potted plants. The exact cause for this has not been determined but it has been found to be mitigated by placing the pots on wooden insulators to keep them off the moist floor, ground or bench. Grounding of the chamber body by any means tends to induce spurious offsets and confound psychrometer operation. This phenomenon is generally obvious so easy to diagnose and take steps to correct. Also, direct sunlight on the psychrometer installation causes large temperature gradients even with insulation and reflective foil coverings on the instruments.

NOTE 6: If you discover a large variation it is usually indicative of some spurious electrical effect (e.g. static) or condensation in the chamber. The safest remedy in all cases is to remove the psychrometer, clean it and reinstall at a new site, being careful to completely seal the old site with silicon grease.

6.8 Temperature Gradient

The temperature gradient which results in measurement errors is that between the measuring junction and the tissue. The assumption that isothermal conditions prevail within the chamber and adjacent tissue almost never holds for in-situ measurements. The stem psychrometer compensates for this error by direct measurement. Gentle nudging of the 'sample thermocouple' (Thermocouple-S) into position is often necessary to ensure that it is extended sufficiently to make contact with the sample surface. This should be done with the aid of a hand lens or dissection microscope and fine forceps. See Handling the Instrument.

The integrated microprocessor measures the temperature gradient, within the chamber between Thermocouple-C (chamber air) and Thermocouple-S (sample temperature). A positive gradient indicates that the sample is cooler than the chamber air. In this case, the absolute value of the calculated error is subtracted from the absolute value of the measured water potential. In other words the sample is at a higher (less negative) water potential than the value determined by the C thermocouple in the chamber air which is at a slightly warmer temperature.

Calculation of the correction in water potential measurement is automatically calculated by converting the measured voltage to temperature. The calibration coefficient for chromel-constantan thermocouples is 61µV/°C. Having assessed the temperature gradient which causes the error in measured water potential, the correction factor, which is itself a temperature dependent variable, is applied. This factor is 8.20 MPa/°C at 25°C and increases to 8.38 MPa/°C at 20°C. The temperature dependence of this factor is dynamically recorded and applied to all readings making the measurements directly applicable across a wide range of variable ambient temperatures.

NOTE 7 the psychrometric reading of water potential is temperature dependent.

If the psychrometer is used at ambient temperatures which differ from the calibration temperature by more than ten degrees, then corrections using the formula should not be strictly relied upon. For example, it is common to calibrate the psychrometer at 25°C. If one routinely uses the instrument at, say, 15°C and applies the correction, an unknown potential error could be introduced. It would be

advisable to calibrate the instrument at or near the temperature at which it will normally be used. A very useful exercise would be to calibrate the instrument at a variety of temperatures and assess the relationship between temperature and calibration coefficient for the individual instruments. This will enhance the reliability of the instrument.

6.9 Condensation:

Temperature gradients which induce condensation on the inner chamber walls should be avoided. For every bar (0.1 MPa) of measured water potential a temperature gradient of 0.012 ^{o}C or more will induce condensation. If that gradient is such that the sample tissue is cooler than the chamber body, then condensation will occur on the sample and most likely be absorbed and redistributed. If, however, the reverse gradient is the case, then condensation will form on the inner chamber walls and introduce an unknown error in measurements. Generally this problem can be spotted before it seriously affects interpretation of measurements.

NOTE 8 : If a gradient favouring condensation on the chamber walls persists (i.e. a negative gradient from Thermocouple-C to Thermocouple-S) then measurements of apparent water potential will tend to rise and approach zero and not vary much between measurements. When it is obvious that this has occurred, remove the instrument, clean and reinstall it.

Under experimental conditions which favour undesirable temperature gradients, such as the cool early hours of the morning before sunrise through until mid morning, the heater can be used to mitigate these problems. It is a 12 volt (DC) resistive heater embedded into the back of the psychrometer chamber. The heating protocol can be adjusted by the user and is automatically controlled by the PSY1.

The exact protocol must remain a subject of trial and error depending on the specific conditions experienced. However, a reasonable approach is to routinely pulse the 12 volt heater for periods of 15 seconds to 1 minute between measurements immediately following a measurement to allow sufficient time for the heat introduced to the chamber to dissipate and return to equilibrium before the next measurement. The appropriate protocol is one which maintains conditions such that condensation will not occur on the chamber walls (i.e. the chamber is warmer than the sample). Allow enough time for extraordinary gradients caused by the heater to dissipate before attempting a measurement. See Measurement Protocols for details on the setting of the chamber heating protocol.

6.10 Osmotic Potential

Osmotic potentials can be measured on extracted sap samples or destructively sampled leaf tissue or leaf discs. These measurements can be made in the lab or in the field. Samples are placed in the calibration lid of the PSY1 stem psychrometer.

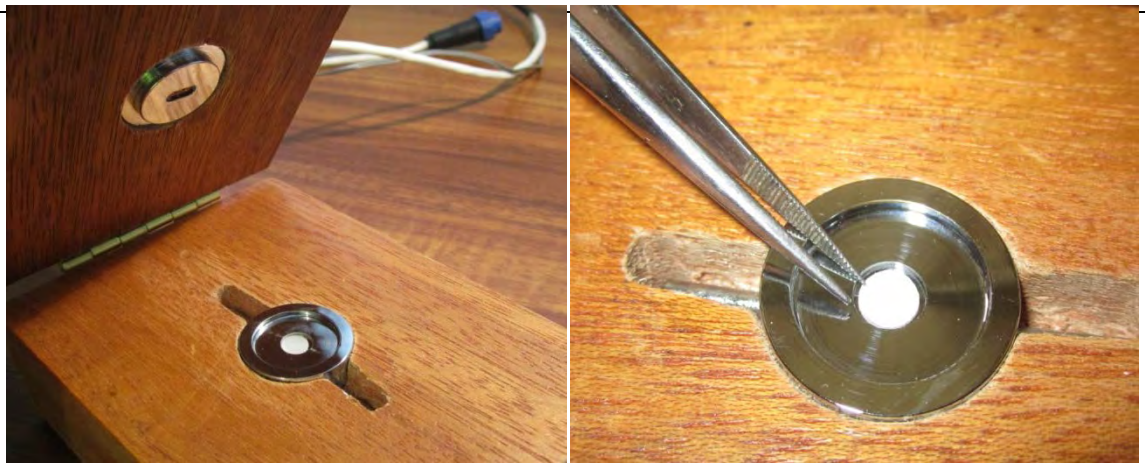
The psychrometer chamber is housed in the Osmotic Potential Insulator (OPI) to provide a thermal insulating jacket around the chamber. This eliminates introduction of thermal gradients caused by a need to handle the chamber to load samples and provides a stable insulated thermal buffer from ambient temperature gradients within the surrounding environment. This enables a very rapid equilibration time between samples.

Photo 4: **PSY1 Stem Psychrometer & Osmotic Potential Insulator**

Osmotic potential measurements are typically performed in a manual process. Using the Graphical User Interface (GUI) the PSY1 provides the user with a "Live" mode or a Manual mode to facilitate osmotic potential measurements.

6.10.1 Collecting an Extracted Sap Sample

An abraded leaf disc or filter paper disc (saturated with extracted sap exudates from a suitably prepared sample using a freezing and physical disruption protocol to separate the symplastic fluid from the cells of the leaf), are placed in the calibration lid. Wrap the leaf in a foil envelope and include a filter paper disk which will become saturated with the expressed cell contents. Place in liquid Nitrogen to freeze then crush it in a vice to physically and mechanically disrupt the cell walls. Place the saturated filter paper disk in the psychrometer calibration lid and measure the osmotic potential following thermal equilibration/stabilization of the psychrometer chamber.



(a) (b)

Photo 5 (a) the psychrometer chamber mounted inside the Osmotic Potential Insulator (OPI) and (b) loading a filter paper disc soaked in an extracted sap solution to measure osmotic potential

7 Charging – Powering the instrument

The PSY1 is a stand-alone instrument designed for long term deployment in remote areas for continuous, unattended logging applications. Each instrument has an internal 4.2V (800 mA) lithium polymer, rechargeable battery. The microprocessor is a low power chip and the instrument functions below 4 V using only 3 mA in general operation. An integrated inverter provides the 12V supply to perform measurement tasks specific to the Psychrometric principle as required.

At the heart of the instrument is a very sophisticated charging circuit that features a non-polarised, two-wire power-bus. This eliminates the chance of damaging the electronics by incorrect wiring of the positive and negative terminals from an external power supply. And, a purpose designed and built internal charging regulator that regulates any supplied DC voltage between 4-30V DC prevents overcharging of the internal battery to ensure a long service life.

NOTE 9: ICT recommends the use of 12V DC power supplies as they are readily available and minimise power loss through regulation thus maximising power efficiency.

This means the PSY1 does not need a solar regulator when using it with a solar panel. The solar panel can be connected directly to the instrument via the two-wire power-bus using the unique power-bus plugs at either end of the instrument. Please see the schematic Connecting Power directly via a solar panel that illustrates the connection.

With a solar panel (or other 12V DC external supply) attached the PSY1 will regulate the charging current from the external source and dynamically trickle charge the internal 4.2V battery. For example, if there is full sunlight it will charge at a maximum rate of 200 mAmp. Where partial sun light or diffuse light (shade) strikes the solar panel the internal battery will still charge, but at a reduced rate as low as only 10 mAmp. The dynamic charging circuit is designed to maximise any and all available light at any time of the day or conditions to ensure maximum possible charge of the battery is achieved.

Because the PSY1 regulates and trickle charges the internal battery no expensive, low impedance cable is required. A common, low cost (and easily available) figure-8 or “lamp cord” cable is all that is required and can be used over long distances to connect an external power supply and/or daisy chain multiple devices together to share a single external power supply.

Powering and charging the instrument is very easy and there are four different options to choose from providing flexibility in experimental design to suit your specific situation. The following diagrams illustrate the use of the unique power-bus plugs and the four different power configuration options that can be used to provide continuous trickle charging of the internal battery for long term deployment.

7.1 PSY1 Current draw

All power requirements are handled via the PSY1 instrument. The current draw is approx 5mA for 30 minute temporal resolution and 4 mA for 60 minutes.

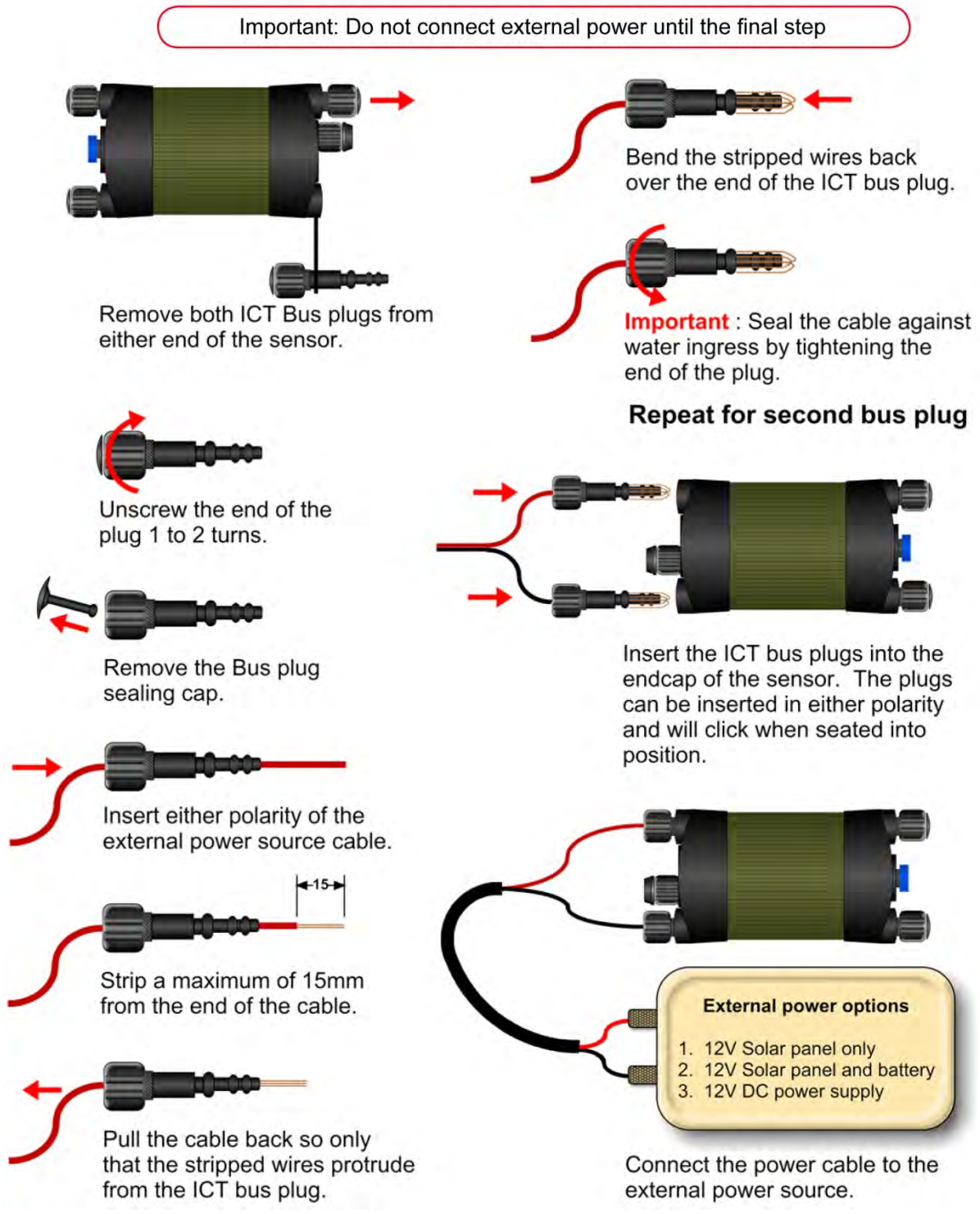
This accounts for the 10 mA Peltier current plus application board of the logger. There is a base draw of 3.5mA continuous, and the application board is only “awake” for a minute every 30 minutes (such as cooling, taking measurements), so approximately 5mA during a 30 minute measurement mode and about 4mA during a 60 minute measurement mode. If you communicate via USB and radio, those values will change, depending on the frequency and duration of communications.

It is possible to operate the PSY1 at hourly intervals for between 3 to 5 days on the internal battery if you are not heating the chamber. If you use a small 5 Amp hr external battery you could operate the PSY1 for a month before needing to exchange the external battery for a charged one.

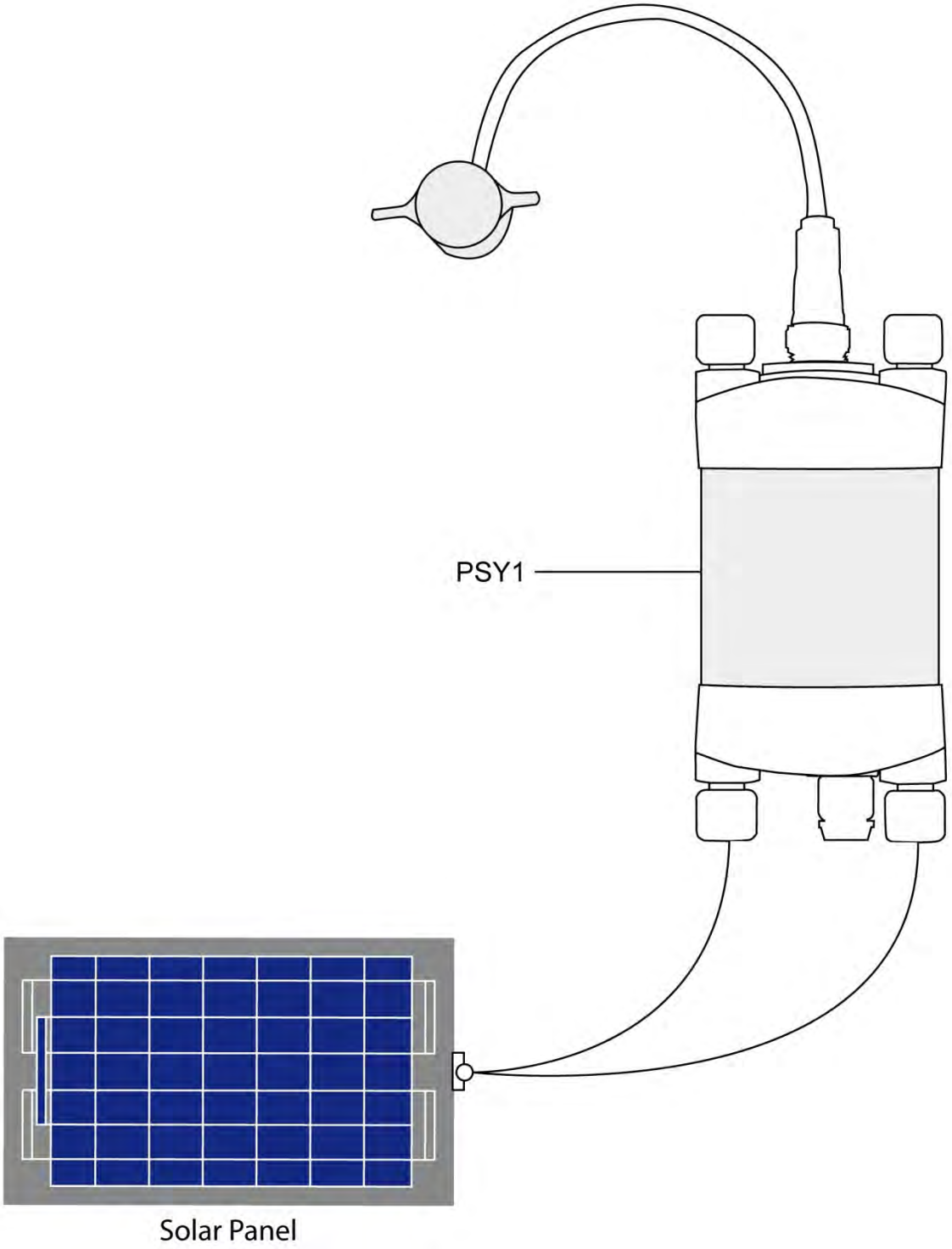
All power is drawn from the internal battery regardless of any external source connected. Hence trickle charging can occur over very long (>100 m) low grade cable just so long as you are above 8 volts by the time you reach the instrument from the source. As the internal battery is 4.2 V Lithium Polymer and inverts to 12V.

7.2 Connecting a Power Supply to the Instrument

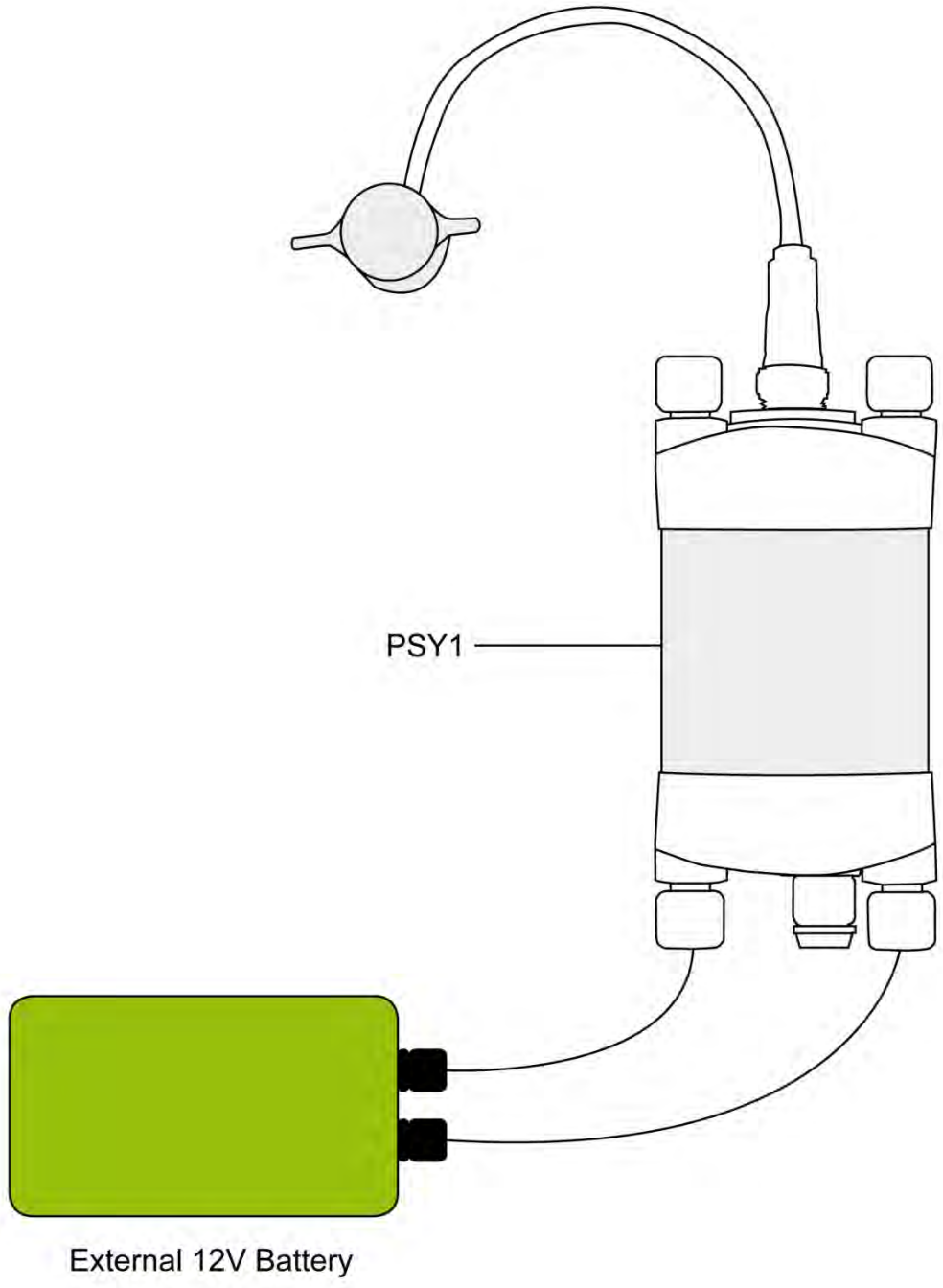
The unique power-bus plug design was developed by ICT to simplify the electrical wiring process. It minimises the need for custom tools in the field requiring only that the outer cable sheath be stripped back to expose the copper wire. As shown below no other tools are required with all necessary components and fixings fully incorporated into the instrument design. Retaining straps ensure the power-bus plugs do not separate from the instrument when removed from the power-bus during wiring preparation and connection of external power.



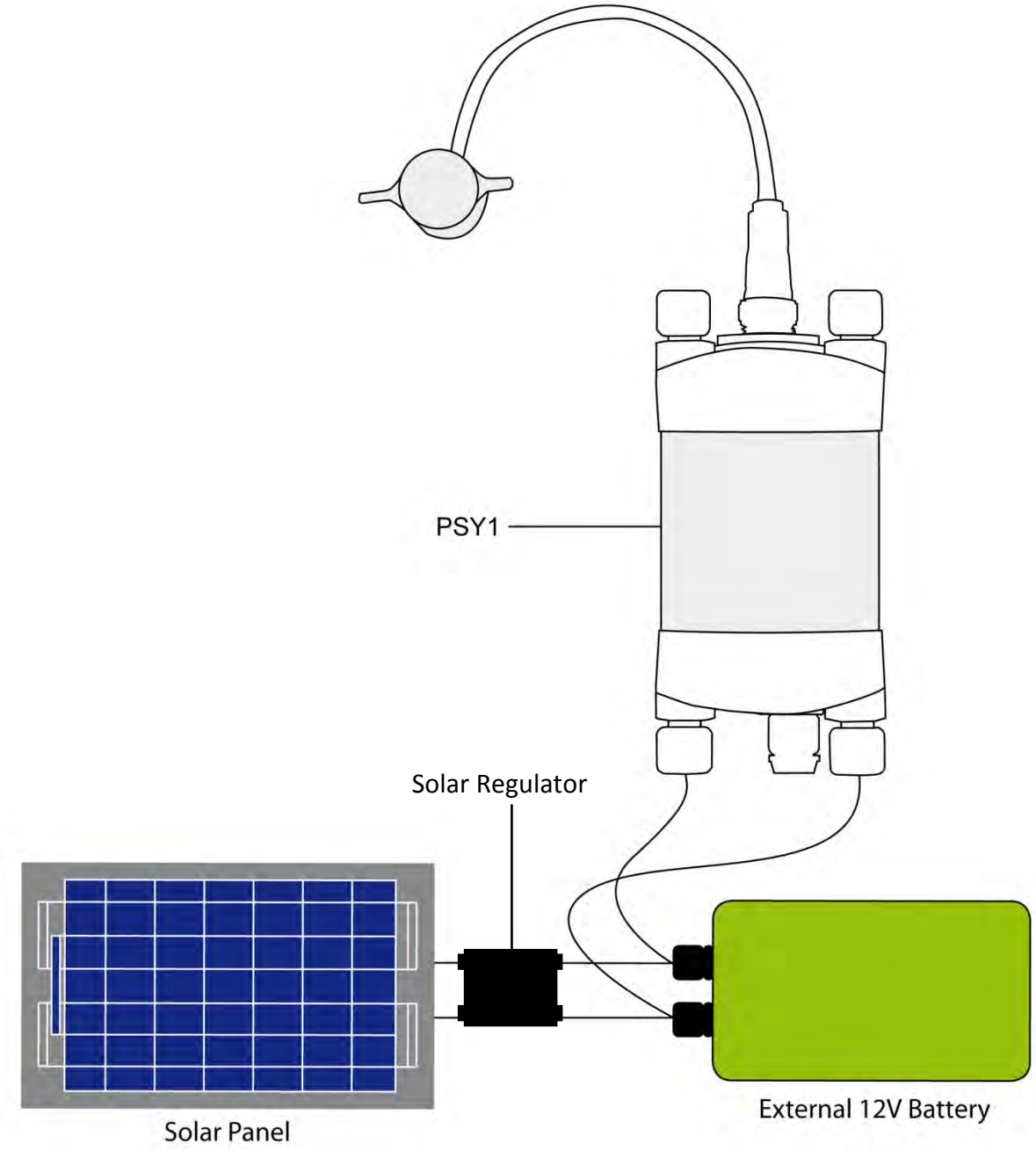
7.3 Connecting Power Directly via Solar Panel



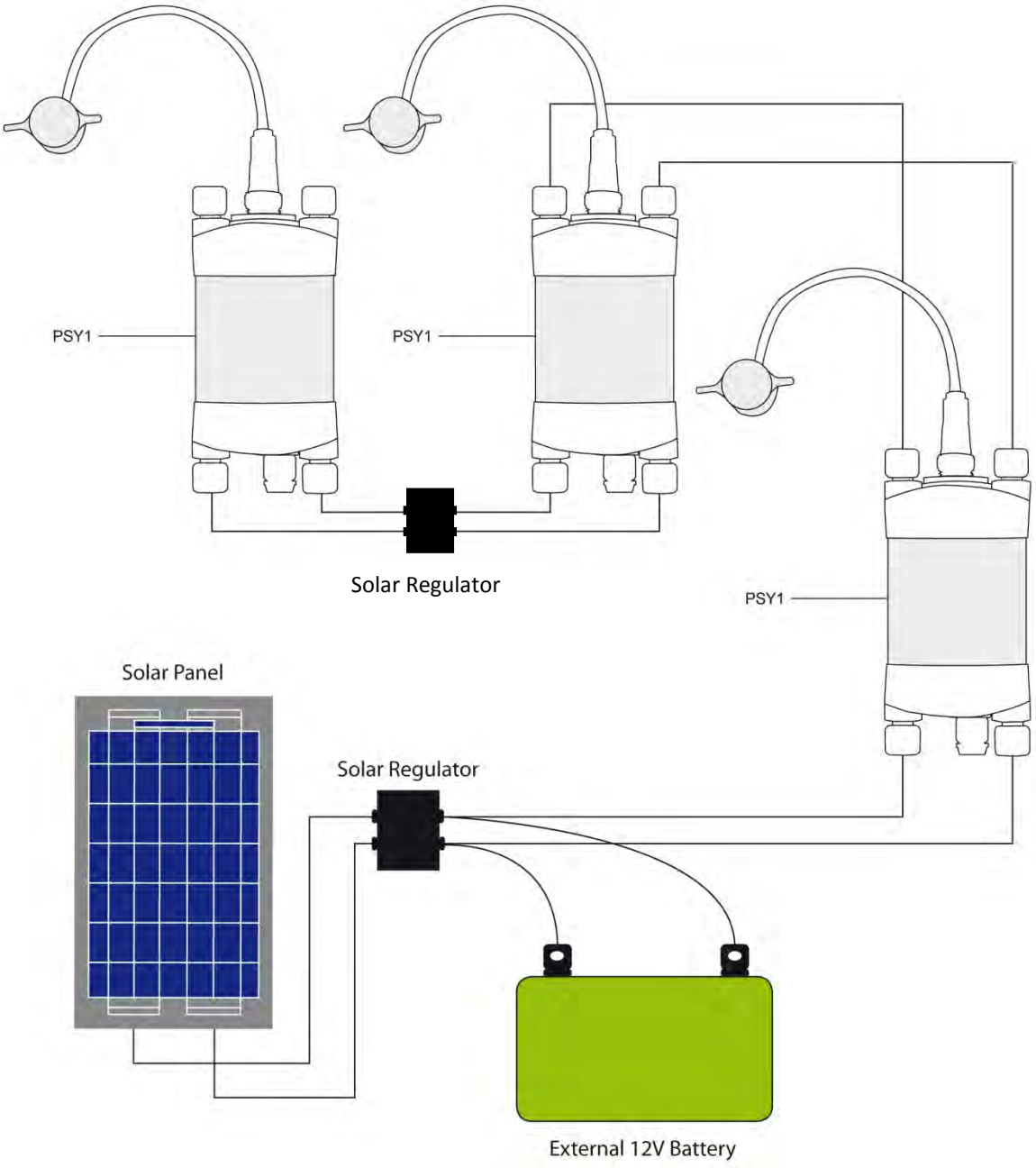
7.4 Connecting Power via External 12V Battery



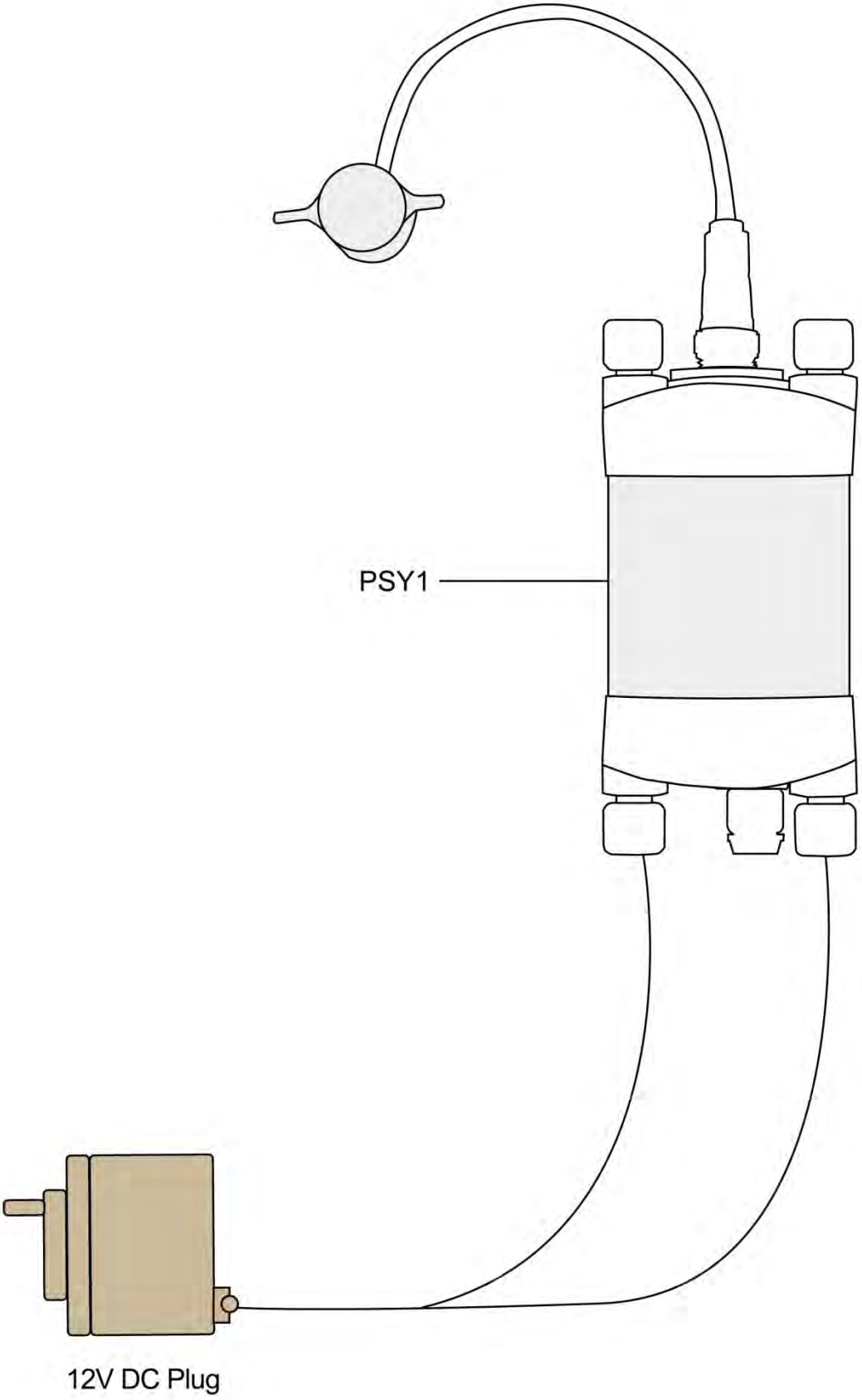
7.5 Connecting Power via External 12V Battery and Solar Panel



7.6 Sharing an External 12V Battery and Solar Panel via Daisy Chaining



7.7 Connecting Power via AC Mains 12V DC Plug Pack



8 Handling the Instrument

The chamber housing is very robust and should withstand even the roughest abuse. However, the delicate sensors are exposed when the calibration lid is removed. Care should be taken to avoid touching the chromel/constantan junctions mounted in the chamber well. Aside from temperature gradients, thermocouple contamination is the most important source of error in the psychrometric determination of water potential. Diagnosing a dirty thermocouple and eliminating this hazard is discussed in detail in Cleaning the Psychrometer.

9 Adjusting Thermocouples

This section outlines the basic procedure for the use of the stem psychrometer and should be read before attempting to inspect or operate the instrument.

VIDEO 11- **Adjusting Thermocouples** - **Watch this BEFORE Opening the Chamber**

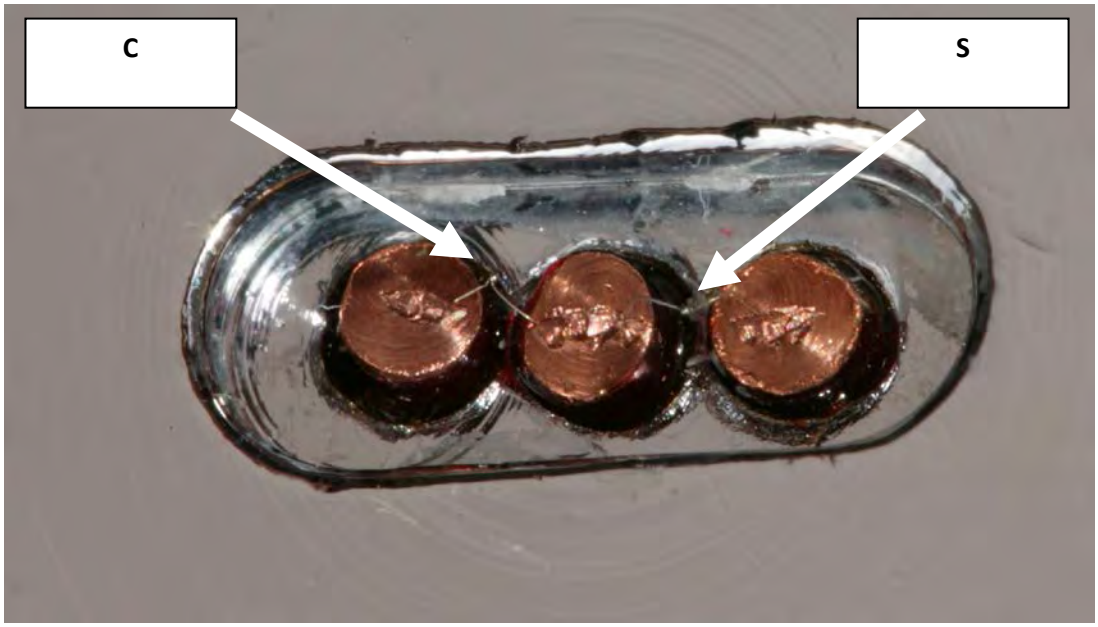


Photo 6 25 µ Chromel/Constantan thermocouples viewed under a dissection microscope at 20X magnification

WARNING $_3$ NEVER grab or pull the thermocouples with forceps. This will break the very fine 25 µ wires and result in the instrument being returned to ICT for factory repair.

The recommended procedure is to use a very fine pair of forceps to push or nudge the thermocouple wires from side to side as this will raise the thermocouple up into a vertical position. It should only be necessary to raise Thermocouple-S into the vertical position. Thermocouple-S must be raised to the face of the psychrometer chamber so that it can make contact with the xylem surface in order to directly measure the stem temperature and thus determine dT

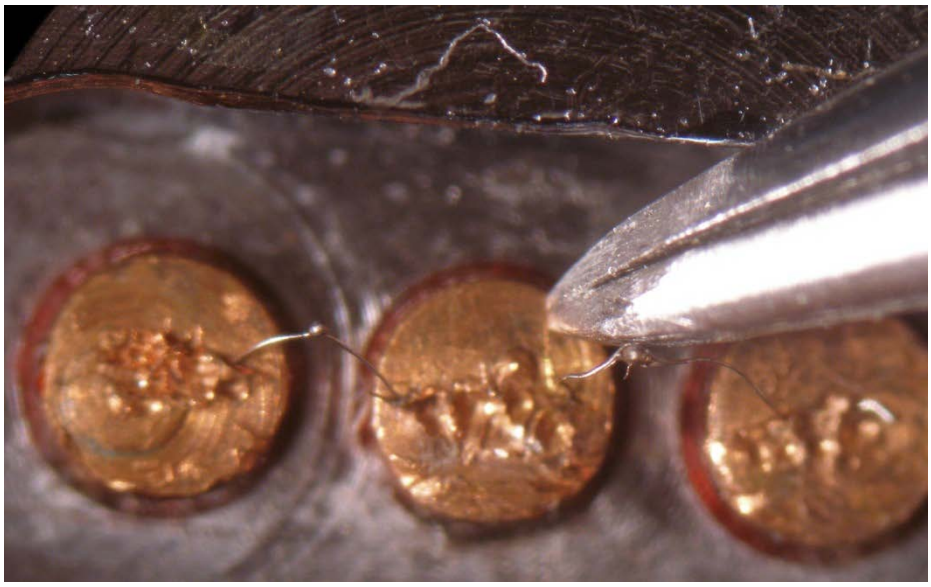


Photo 7 Adjusting Thermocouple-S vertically to the face of the chamber

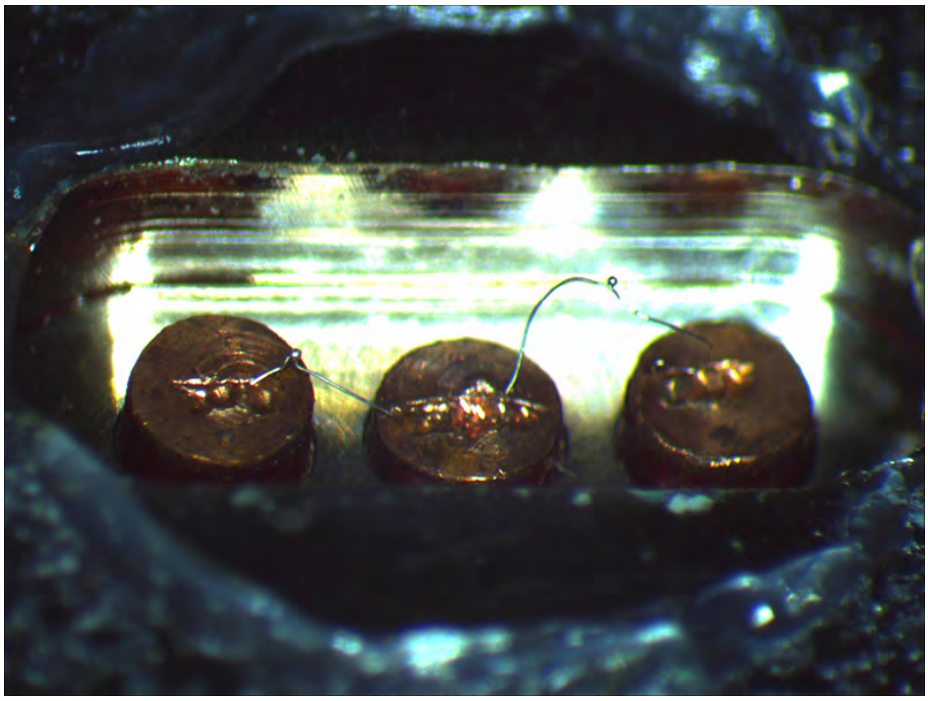


Photo 8 Thermocouple-S viewed from the side sitting just above the chamber surface.

10 Cleaning the Psychrometer

The need for cleaning the stem psychrometer may not always be obvious from visual observation even under a 20 x dissection microscope. The Stem Psychrometer consists of two very small welded thermocouples using very fine wire only 25 µm in diameter. This makes the sensor very sensitive to measuring water potential but equally as sensitive to dirt and even mild oxidation. It is recommended that before starting any measurements you clean the thermocouples.

NOTE 10 - This should even be done upon receipt of new instruments from ICT or at the commencement of a field campaign, especially if they have been stored for any length of time.

WARNING $_4$ – NEVER store the stem psychrometers without first cleaning.

Diagnosing a dirty thermocouple that is not visually obvious is done by plotting the Peltier cooling curve and interpreting psychrometric plateau and the thermocouple response as it returns to zero microvolts within the measurement period. This is covered in detail in section diagnosing a dirty thermocouple.

Conversely, badly contaminated and dirty psychrometers can easily be identified from visual observation, in some cases even without the use of a 20 x dissection microscope.

Photo 9 A heavily contaminated stem psychrometer in which the chamber well has been filled with vacuum grease and plant tissue or callus, this type of contamination is clearly obvious from visual observation

10.1 Cleaning routine

The stem psychrometer requires a strong organic solvent to clean dirt and/or organic matter that may have entered, and contaminated the chamber and thermocouples. The organic solvent will dissolve the contaminants, but both the organic solvent and dissolved contaminants must be flushed from the chamber using distilled water. Failure to do so will result in the dissolved contaminants precipitating out of solution as the solvent dries (evaporates) and the thermocouples being recoated with a film of contamination and not being cleaned.

The organic solvent recommended for cleaning the psychrometer is Chloroform ($CHCl_3$). This is a standard analytical reagent available in most laboratories; however it is regulated under strict safety controls that may make it difficult to access and definitely difficult to transport safely in the field. An alternative cleaning agent that may be substituted for Chloroform is electrical contact cleaner. Recommended electrical contact cleaners and cleaning procedures for cleaning the psychrometer using both options are documented below.

Photo 10 Analytical Reagent Chloroform ($CHCl_3$)

Photo 11 CRC - QD Electronic Cleaner.

10.1.1 Cleaning the psychrometer using Chloroform

VIDEO 12 - Watch how to clean the Psychrometer using Chloroform

a. Invert the psychrometer chamber and flood the chamber well with the organic solvent, (chloroform). This is done using an eye dropper to deliver several drops of Chloroform directly onto the thermocouples. Let stand for between 5 to 10 seconds (longer if severely contaminated) ensuring not to allow the chloroform to evaporate.

WARNING 5 - If chloroform is allowed to evaporate while in the chamber well of the Psychrometer it will further contaminate the thermocouples. Any and all of the organic compounds dissolved by the chloroform must be washed out with distilled water. Failure to do so results in these dissolved contaminants being evenly distributed and coating the thermocouple further exacerbating the original contamination. This contamination will be visible as a fine white film.

b. Then, using a wash bottle of distilled water, immediately rinse away the dissolved contaminants by squirting a steady stream of water into the chamber well, rinsing continuously for approx 3-5 seconds.
c. Next use a Kim Wipe or other such lint free tissue, and place a corner of the tissue in the outer edge of the chamber well. This will wick the bulk of the water up out of the chamber well.

WARNING 6 - Be extremely careful not to touch the thermocouples with the tissue and do not attempt to rub the tissue within the chamber. The intention is merely to absorb the bulk of the free water not to completely dry the chamber well.

d. Finally, blow dry with a controlled stream of compressed air (20 to 30 psi). The drying phase is important as residual water must be removed from the chamber well. Stubborn drops may reside around the copper posts and sustained streams of compressed air may be required to remove all the water.

This cleaning process may be required to be performed several times to achieve a thorough cleaning of the stem Psychrometer depending upon the severity of the contamination. Once satisfied that the stem Psychrometer is clean, connect the unit to the PSY1 and perform a verification test, see (Appendix 1).

At this point you should also visually check the position of Thermocouple-S using a 20 x dissection microscope. If Thermocouple-S requires adjustment follow the instructions in the Setup Procedure. The stem psychrometer is now clean and ready for deployment.

10.1.2 Cleaning the psychrometer using Electronic Contact Cleaner

Electrical Contact Cleaners are available from a number of commercial outlets. Whilst these are all intended for the same basic purpose, that being to clean electrical contacts leaving no residue for high electrical conduction, they utilise a variety of organic solvents at varying concentrations. Therefore, not all electrical contact cleaners will perform to the same level of efficacy in cleaning the stem psychrometer. ICT has evaluated a range of Electronic Contact Cleaners and provided a list of recommended options. Appendix 22.2 Electronic Contact Cleaners, lists manufacturer web sites and MSDS links to enable you to source a cleaner locally.

WARNING 7 – Do not use a De-greaser Spray or a contact cleaner that is oil based.

NOTE 11 Not all electronic cleaners may be available in your country

VIDEO 13 - Watch how to clean the psychrometer using Electrical Contact Cleaner

a. In an open well-ventilated area (preferably outdoors), invert and hold the psychrometer chamber at 45 ° to the ground facing away from your body. Shake the can well (following the manufacturer's directions) and spray a steady stream of electronic contact cleaner into the chamber well for approx 2 seconds ensuring the chamber well is fully saturated. Repeat this process at least twice leaving the chamber well fully saturated.

WARNING 8 – the physical pressure of the propellant used in the electronic cleaner will aid in dislodging contamination, but will not fully remove the dissolved organics that will invariably remain in the chamber well in solution. This contaminated solution must be flushed with distilled water prior to it evaporating.

b. Then, using a wash bottle of distilled water, immediately rinse away the dissolved contaminants by squirting a steady stream of water into the chamber well, rinsing continuously for approx 3-5 seconds.
c. Next use a Kim Wipe or other such lint free tissue, and place a corner of the tissue in the outer edge of the chamber well. This will wick the bulk of the water up out of the chamber well.

WARNING 9 - Be extremely careful not to touch the thermocouples with the tissue and do not attempt to rub the tissue within the chamber. The intention is merely to absorb the bulk of the free water not to completely dry the chamber well.

d. Finally, blow dry with a controlled stream of compressed air (20 to 30 psi). The drying phase is important as residual water must be removed from the chamber well. Stubborn drops may reside around the copper posts and sustained streams of compressed air may be required to remove all the water.

This cleaning process may be required to be performed several times to achieve a thorough cleaning of the stem Psychrometer depending upon the severity of the contamination. Once satisfied that the stem Psychrometer is clean, connect the unit to the PSY1 and perform a verification test (Appendix 1).

At this point you should also visually check the position of Thermocouple-S using a 20 x dissection microscope (or a 10 x pocket hand lens if in the field). If Thermocouple-S requires adjustment follow the instructions in Chapter 9 Setup Procedure. The stem Psychrometer is now clean and ready for deployment.

NOTE 12 a pre-packaged pressurised can of pure, moisture free, compressed air is recommended to ensure sufficient pressure to drive out microscopic beads of water from around the copper posts and is a convenient tool in the field.

Photo 12 CRC Air Brush Compressed Air

Photo 13 Dick Smith Air Jet Spray

10.2 Diagnosing a Dirty Thermocouple

Detection and diagnosis of a contaminated thermocouple is easily accomplished with the PSY1 in Manual mode.

Place a known water potential sample (1.0 Molal NaCl solution) on a filter paper disk in the calibration lid of the Psychrometer. Set the PSY1 to Manual mode and perform a measurement.

If the thermocouple is very dirty the measured result will clearly indicate a problem. This can be seen in the "Dialogue box" where the results of the manual measurement are immediately displayed upon completion of the measurement. The key factor to review is the Wet Bulb Depression. If water had been able to be condensed on the thermocouple it would have cooled generating a µV output in the range of 19 µV for a 1.0 Molal solution. In this example, there is effectively no change from the Electronic Dry Bulb Offset (measured prior to each measurement), remaining at -0.15 µV.

In less obvious cases the Psychrometric plateau will show a less crisp and clean response with a typical, long slow drift back to zero reference or perhaps even fail to reach zero within the measurement window.

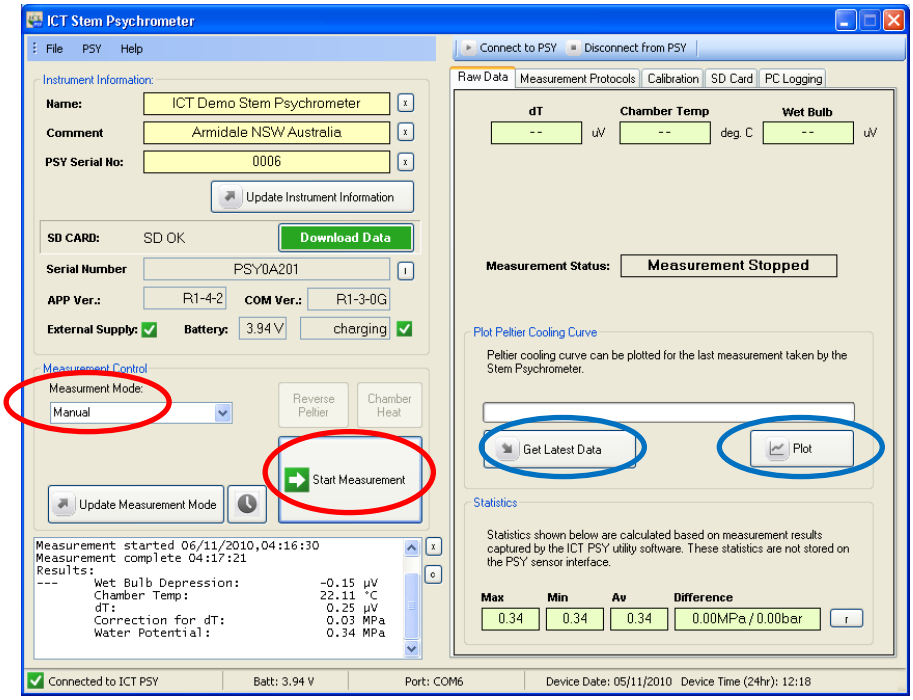


Figure 4 Manual mode Configuration and operation

Click on the "**Get Latest Data**" icon and then plot the data by clicking on the "**Plot**" icon. The Peltier cooling pulse is graphed and can be reviewed to illustrate the numerical results from the "Dialogue box".

VIDEO 14 Diagnosing Dirty Thermocouples provides explanation and examples of the effect of a dirty thermocouple on the shape of the Psychrometric plateau

The flat line (shown in Figure 5) with no evidence of Peltier cooling, which would generate a positive µV response, is an extreme example of a dirty thermocouple and clearly shows that water has not been able to be condensed on the thermocouple due to severe contamination probably by silicon grease or perhaps plant material.

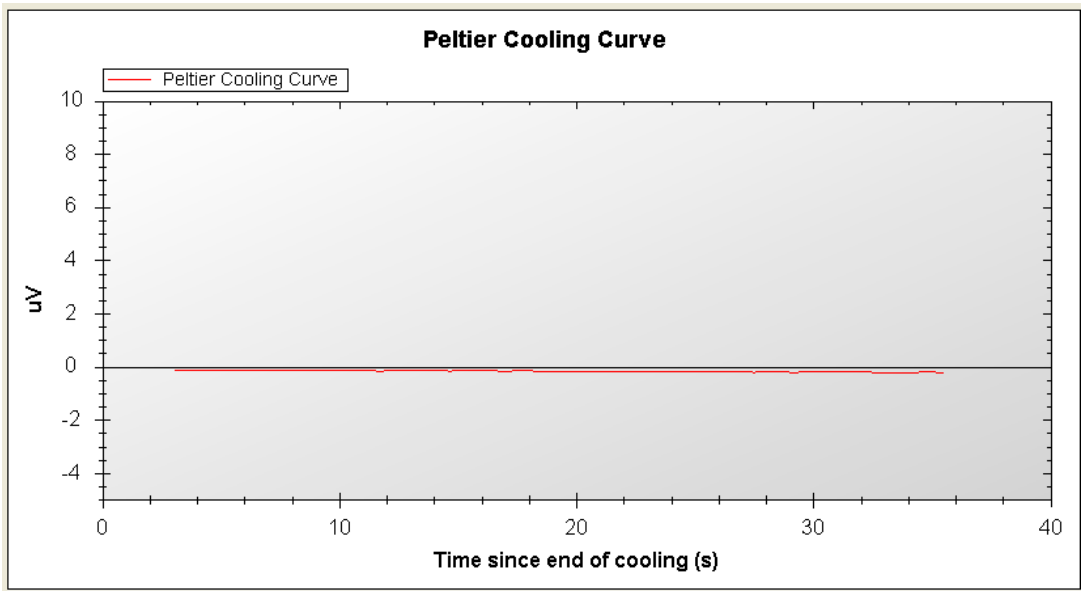


Figure 5 Shows an extreme response of a dirty Thermocouple-C that requires cleaning as no water could be condensed on the thermocouple.

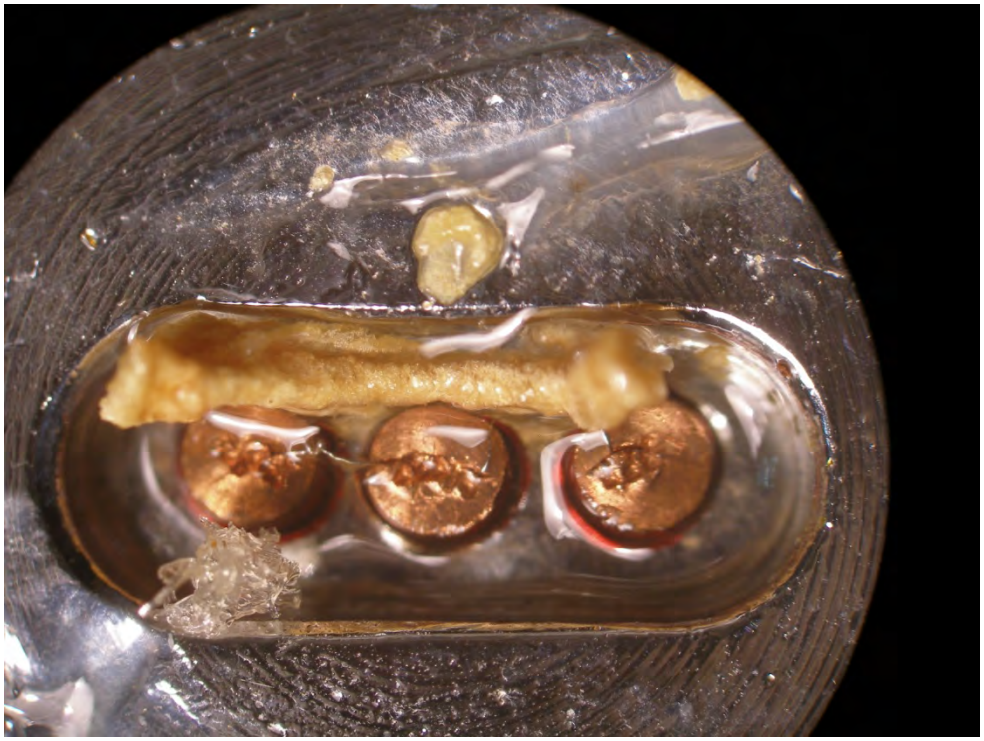


Photo 14 the corresponding contamination of the thermocouples that results in no Wet Bulb Depression being generated as water vapour could not be condensed on Thermocouple-C.

The second example (Figure 6 below) is less extreme showing a more subtle response yet still indicating a dirty thermocouple. The thermocouple output is lower than expected (approx only 13 µV at 6 seconds after the end of cooling), and instead of the cooling curve dropping sharply to zero, as the thermocouple warms quickly due to the condensed water evaporating, it has a slow drift back towards zero. In fact even 30 seconds after the completion of the measurement all of the condensed water has yet to fully evaporate, trapped by the organic contamination of the thermocouple resulting in the failure of the thermocouple to warm back to zero or the starting reference temperature (zero µV).

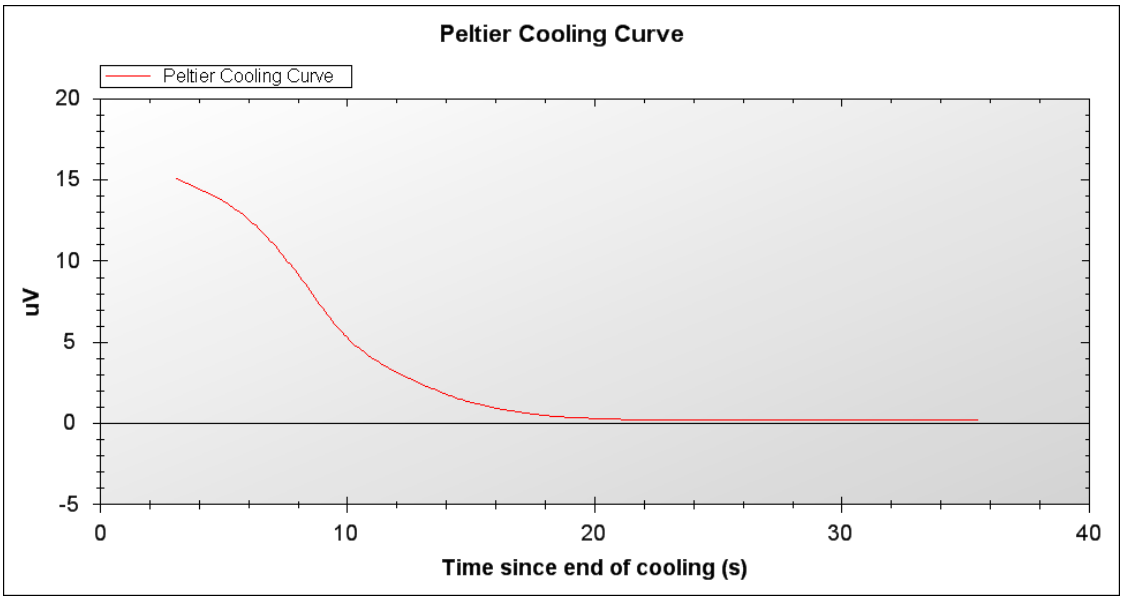


Figure 6 the characteristic response of a dirty Thermocouple-C that requires cleaning

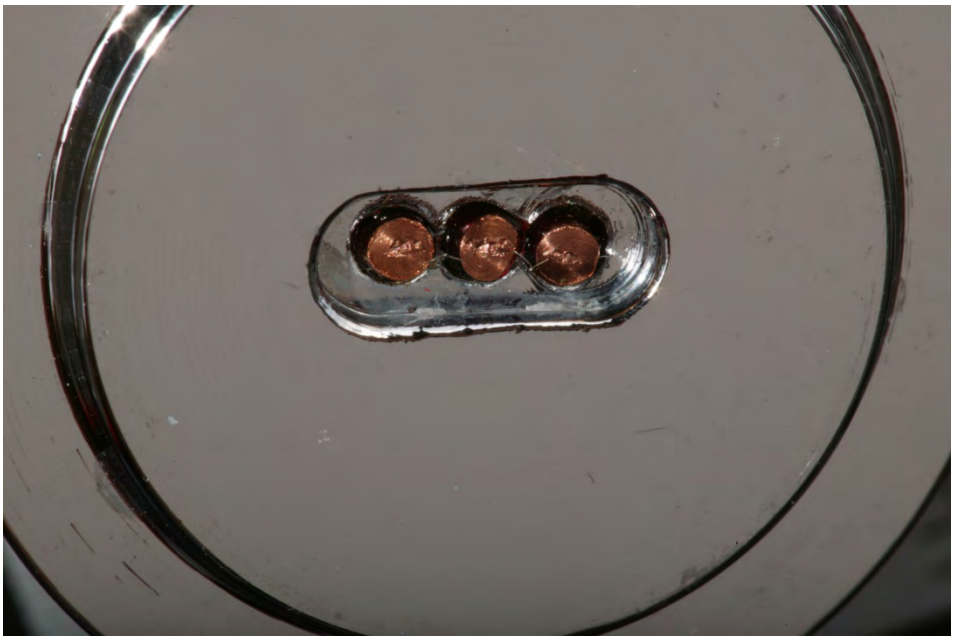


Photo 15 the corresponding psychrometer that generated the Peltier cooling curve in Figure6. Note there is no visually obvious dirt or contamination. This is why it is important to clean and test with a 1.0 Molal NaCl solution before deployment

Figure 7 shows the results after the chamber was cleaned. The results are now as expected; a Wet Bulb Depression in the range of approx 19 µV, producing a Water Potential of -4.64 MPa for a 1.0 molal solution. The thermocouple had been dirtied by a small amount of organic material and mild oxidation of the thermocouples. This disrupted the process of condensation and evaporation of water on the thermocouple. Once the contamination had been cleaned water could fully condense on the surface of the thermocouple and fully evaporate from the thermocouple leaving it completely dry and rapidly returning to zero. No microscopic beads of water remained trapped on the thermocouple by organic contaminants disrupting the evaporation process and causing a thermal offset or interference.

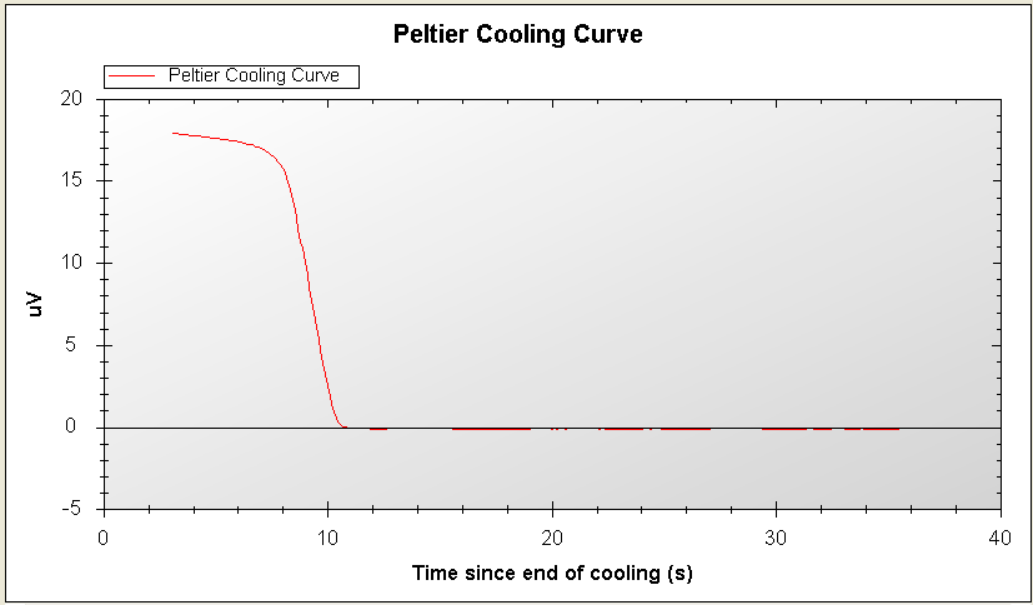


Figure 7 the good characteristic response of a clean Thermocouple-C

CAUTION 1 Sometimes the process of cleaning can reposition thermocouples in awkward positions that make simple manipulations tricky when positioning Thermocouple-S for measurement. Be sure to take extra care and use a 20X dissection microscope to reposition the thermocouple. See Handling the Instrument and adjusting thermocouples for detailed instruction to minimise the possibility of damage to the thermocouples.

10.3 Storing the Stem Psychrometers

It is not always practical to clean the stem psychrometers after de-installation whilst in the field. However, this does not mean that they can be left until you next need them for a future experiment. They must be cleaned upon return to the lab and prior to storage.

Oxidation of the copper posts within the chamber of the psychrometer may affect the measured water potential. If the chamber is not cleaned and the copper posts are corroded, the psychrometer may require factory repair. Corrosion is indicated by the green colouration on the copper posts. It may be necessary to make the observation of this corrosion using a 20X microscope to be sure that the electrodes are not corroded and are suitable for use.

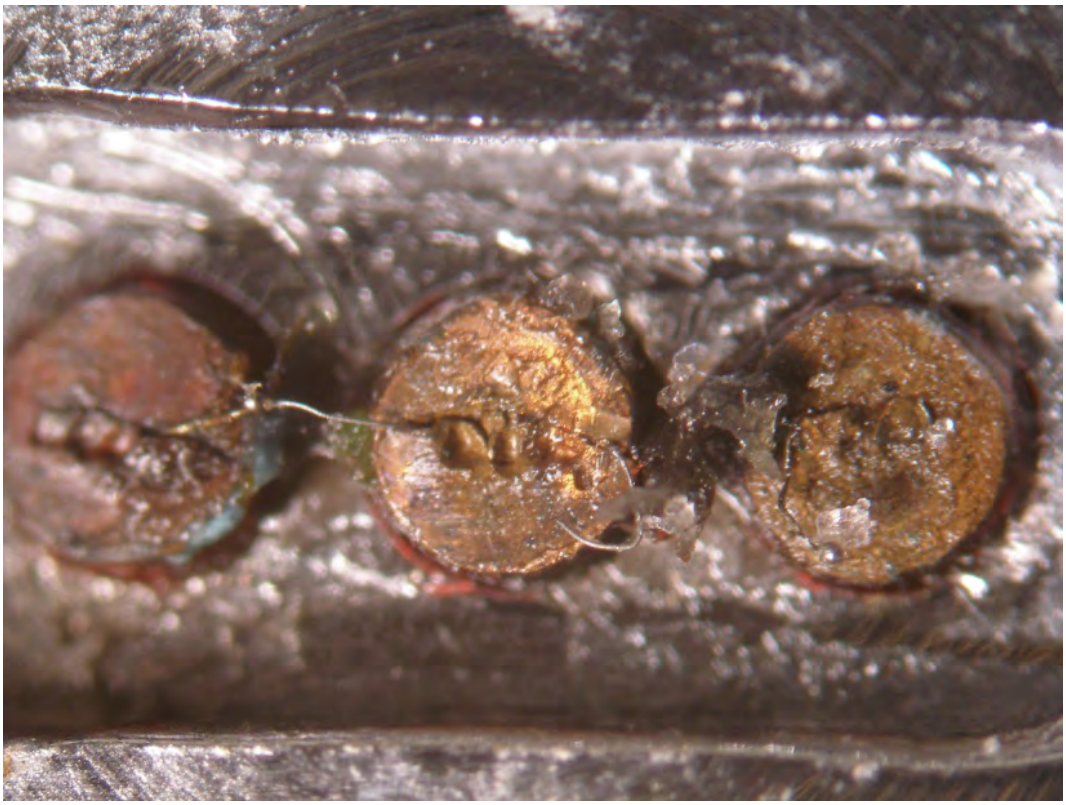


Photo 16 Corroded Copper posts and heavily contaminated psychrometer chamber well with broken thermocouple. DO NOT store a stem psychrometer that looks like this. Return it immediately to ICT for repair or replacement.

WARNING 10 Failure to clean the psychrometers after use and prior to storage WILL result in damage to the very fine 25 µm wires of the thermocouples and result in the instrument needing to be returned to ICT for factory repair.

It is imperative that prior to storing the psychrometers you repeat the full cleaning process, ensuring that they are dry before sealing the chamber.

Use a small smear of vacuum grease on the mating surface of the chamber and the calibration lid for a good air tight seal for storage.

a. Then use the label tape to provide a physical seal around the mating join of the chamber and the calibration lid.
b. Use a #30 rubber band wrapped over the chamber from one handle of the calibration lid to the other to provide a second physical restraint for the calibration lid.
c. Finally, wrap the psychrometer in a brown paper bag and store in a dry, safe and secure location ready for the next field campaign.

NOTE 13 - Dow Corning high vacuum grease (150 gram tubes) is inert, heat stable, silicone grease and is recommended for use in sealing the psychrometer chamber and calibration lid. Products such as petroleum jelly or Vaseline cannot be used as it melts at a very low temperature and leaks into the chamber. Application of several (2-3) small drops on the lid is all that is necessary to seal the calibration lid to the chamber. Apply 2-3 drops and then once the calibration lid is attached to the psychrometer, twist the two surfaces to spread the vacuum grease and form a seal.

VIDEO 15 – Watch how to apply the sealant to the calibration lid

11 Software & USB Driver Installation

11.1 Instrument Set-up and Configuration

NOTE: All changes that you make and confirm by clicking the relevant Update icon will be stored in non-volatile memory. That is, they will be retained even if you turn the power off and on.

11.2 PSY1 Utility Software

NOTE: All software described in the proceeding section are included on the ICT Installation DVD and on the MicroSD card installed in the instrument.

11.2.1 Installation:

A Graphical User Interface (GUI) is used to configure and operate the PSY1 Stem Psychrometer. The GUI or Utility Software operates on Microsoft Windows Operating Systems (OS) and is compatible with Windows XP, Windows Vista and Windows 7.

a. **Install the USB driver ict-usb-driver.exe** This is an executable file that requires no Windows driver Wizard to install. Simply double click on the executable file and the USB driver will automatically install correctly.

b. NOTE: the USB driver can be downloaded from the ICT web site www.ictinternational.com/download/usb-driver/ict-usb-driver.exe

c. Install the software by running the Setup file. Double click on the setup file psy1-r2-0-1-7-setup.msi

d. **NOTE:** you can check for and download the latest version of software from the ICT web site http://www.ictinternational.com/downloads.html

e. Follows the prompts of the Install wizard

f. If necessary install Windows DotNET from the installation CD when prompted. Then complete the installation. An icon will be installed on the Desktop of your PC to run the software.

NOTE: Microsoft System Minimum Requirements

DotNet Framework is free software supplied by Microsoft in all Operating Systems. Dependent upon the age of your PC and the way in which it was configured at the time of manufacture the DotNet software may not have been installed as part of the standard operating system.

ICT International utilises the DotNet programming environment to run the ICT utility software and therefore requires that it be installed on the PC prior to installing the ICT utility software. The ICT installation wizard automatically checks your PC's configuration and will prompt you if DotNet is not installed or an older version of DotNet is installed on your PC. In either case you will need to install DotNet3.5 before proceeding and completing the installation of the ICT utility software. This is a free software download from the Microsoft web site.

ICT has provided the direct Hyperlink for your convenience.
http://download.microsoft.com/download/6/0/f/60fc5854-3cb8-4892-b6db-bd4f42510f28/dotnetfx35.exe

Alternatively, if this link does not work try the following:

http://www.microsoft.com/downloads/en/details.aspx?FamilyID=333325fd-ae52-4e35-b531-508d977d32a6

Scroll to the bottom of the page and click on the following link:

NOTE 14 *the full redistributable download file (300MB) has been provided for you on the ICT Software DVD that came with your instrument and can also be found on the Micro SD card installed in your Instrument. These links are provided as a convenience should you not be able to find the dotNet install file in either of these locations. DotNet Framework is a minimum requirement. Only install if required to. The listed links are to an external site and may change without notice. If these links are not functional, then search Microsoft Downloads page www.microsoft.com/downloads for current locations and links.*

12 Turn the Instrument on

12.1 Turn the PSY1 ON

The PSY1 has a physical power switch located inside the USB communication access port. To access this switch remove the communications access port bung by unscrewing the bung.

NOTE 15: the bung consists of two parts (a) the bung which is the knurled large portion of the bung and (b) the smaller Gore-Tex cap. You must unscrew the whole bung by turning the larger knurled portion of the bung otherwise you will not gain full access to the communications port.

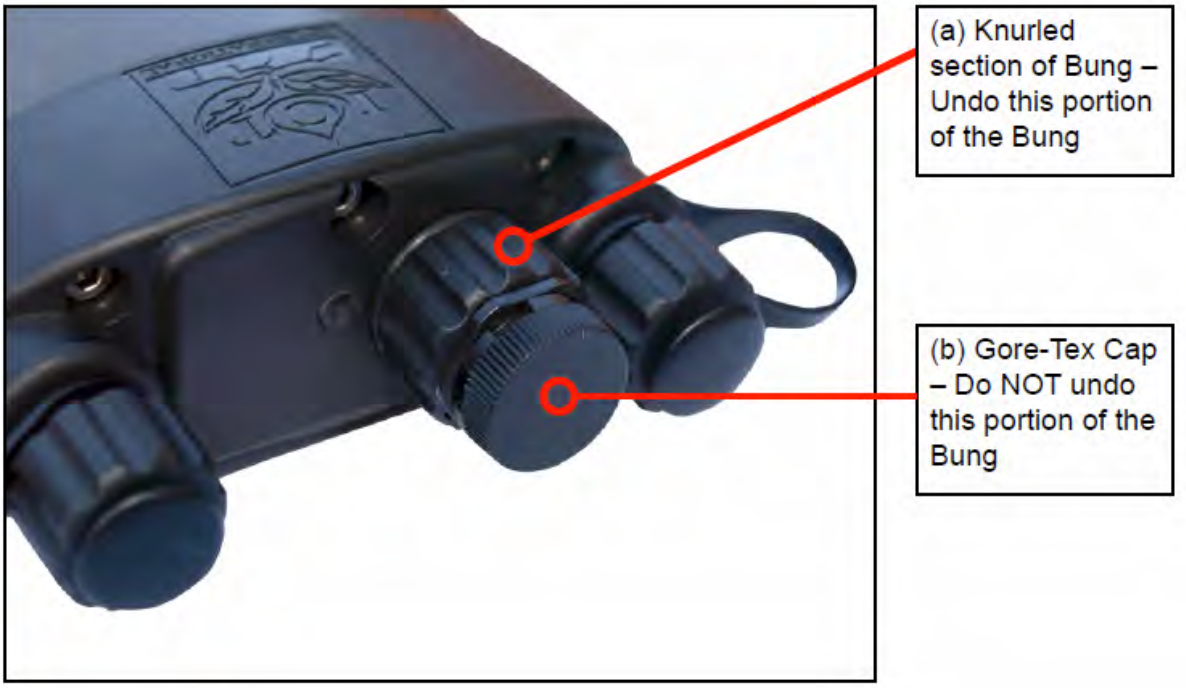


Photo 17 The Power switch is located below the knurled bung

The power switch is located above the USB port. It is a small black button.

NOTE 16 in most cases the user should be able to use their finger to reach inside the communications access port. The point of the finger can rest gently on the USB port allowing the fingernail to rock forward and depress the switch. VERY LITTLE force is required to depress the power switch. If you find this technique difficult you can use a small flat blade screw driver or tweezers supplied by ICT to gently depress the switch.

To turn the PSY1 on, press and hold the switch for approx 1 second. You will see the **Green** LED turn on. The LED will remain **Green** for approx 10 to 15 seconds before turning off. The LED will then Flash **Green** once every 10 seconds to confirm that the unit is powered on.

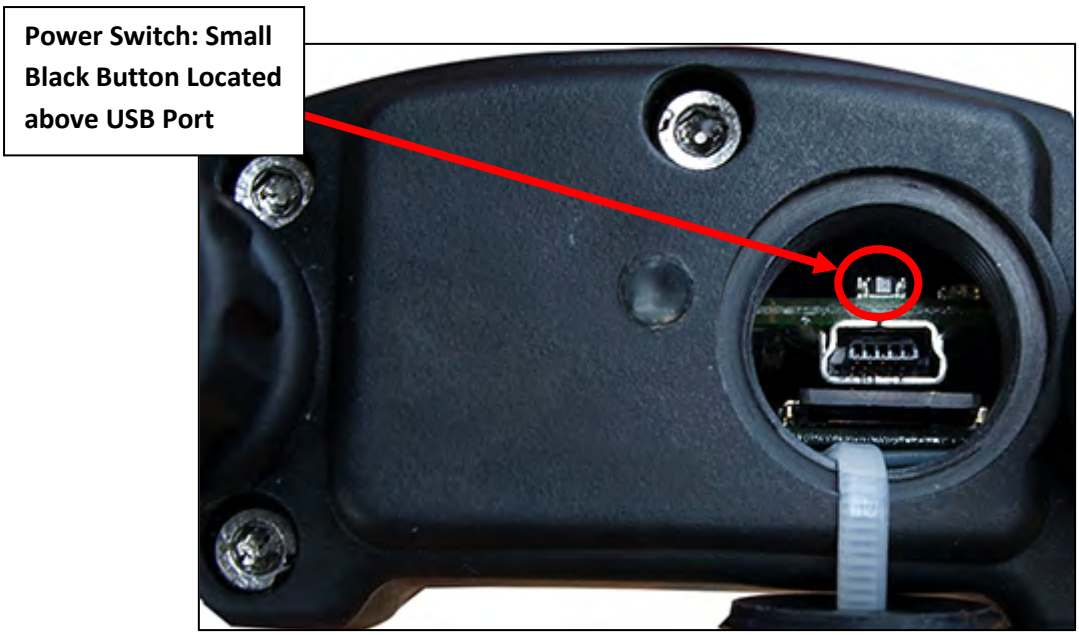


Photo 18 PSY1 Power Switch

NOTE 17: The PSY1 can also be automatically powered up by connecting it to a 12V DC power supply. This can either be in the form of a 12V DC mains power plug pack, a solar panel, solar panel & 12V battery direct to the instrument or through a shared power distribution system in which a large solar panel and battery provide power through a distributed (wired) network to any or all instruments connected (see Charging – Powering the Instrument).

12.2 Turning the PSY1 OFF

The PSY1 DOES NOT turn off automatically. If external power is disconnected from the instrument it will continue to operate from and discharge the internal battery. It **MUST** be turned **OFF** manually. This can be done by using the power switch. To turn the device off press and hold the power switch for approx. 3 seconds. The LED will alternately flash **Red** then **Green** for a few seconds before stopping and all lights are extinguished.

The PSY1 can also be turned off via the GUI software. From the File menu select “Power-Off PSY1”. The LED will alternately flash **Red** then **Green** for a few seconds before stopping and all lights are extinguished. The Instrument will turn off. Confirmation of this is positively reinforced by the software automatically disconnecting. No further current will be drawn from the internal battery. The Instrument is now ready for transport or storage.

NOTE 18: Whilst the PSY1 is connected to external 12V power it cannot be turned off either by using the manual power switch or the software function. Pressing and holding the power switch will just display a Green LED. Using the software will display the warning “External Power Connected” and the software will not automatically disconnect.

13 Communications – Connect to the Instrument

Start the software by double clicking the PSY icon on the desk top of your PC.

13.1.1 The opening Splash Screen displays the following:

1. type of instrument being operated – Stem Psychrometer
2. The connection Status – Not Connected
3. Product Version – 2.0.1.7
4. Release Date – 20/11/2010
5. File Menu along the top of the Window
6. Function buttons
    a. Connect to PSY
    b. Disconnect from PSY

Figure 8 PSY1 Software Splash Screen

NOTE 19: the "Disconnect from PSY" icon is greyed out as the instrument is not connected

13.1.2 A status bar along the bottom of the window

A status bar along the bottom of the window

a. Not Connected to ICT PSY
b. Battery Voltage

NOTE 20: the Battery Voltage of the internal battery of the PSY1 will be displayed upon initiation of the connection. The integrated voltmeter measures the internal battery voltage as soon as a connection is initiated and displays it in the status bar. This provides a diagnostic check during the connection process and prevents frustration that would otherwise occur should the instrument not be able to connect due to a flat battery.

c. Please Select Device

NOTE 21: The PSY1 is a Plug & Play USB device. Once connected to a USB port Windows automatically detects it and allocates it a COM port. You do not need to select or configure the COM port. Once connected the allocated COM port will be displayed here.

13.1.3 *Connect to PSY*

To establish a connection click ***"Connect to PSY"*** There are two ways of connecting to the PSY1 either via direct USB connection or via wireless RF Modem.

13.2 USB Connection:

13.2.1 USB Connection Type

Drop down the ***"Connection Type"*** box (located in the bottom left hand corner of the screen) and select USB.

If the message ***"No compatible devices found"*** is displayed before proceeding to click the ***"Find Devices"*** icon please check the following:

F

Figure 9 Device Selection Window

(a) The Instrument is turned on – (see section Turn the PSY1 ON)

(b) You are connected to a device – A USB cable must be connected between the PC and the USB port of the instrument.

(c) You are connected to the correct device that is compatible with the Utility software you are using e.g., PSY software will only connect to a PSY1 Stem Psychrometer not an SFM1 Sap Flow Meter. The software automatically recognizes the type of device and will not connect to instruments that operate on different principles of operation.

13.2.2 USB Find Devices

Now, click the ***"Find Devices"*** icon.

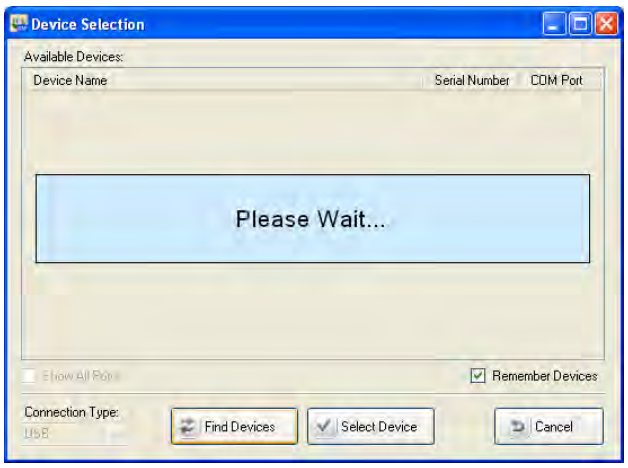


Figure 10 Device Selection Window searching for the connected device

NOTE 22: To eliminate the need to conduct the *"Find Devices"* routine each time you run the software you can tick the *"Remember Devices"* check box. Next time you click on *"Connect to PSY"* the last instrument connected will already be displayed in the list and you can connect to it either by highlighting the device and clicking on *"Select Device"* or double clicking on the device name.

After polling all compatible devices the compatible device that is connected is displayed.

Figure 11 Device Selection Window reporting the device that was found connected

13.2.3 USB Select Device

You can now select the device by clicking on it with the mouse to highlight the device and then clicking on ***"Select Device"***. Alternatively, you can simply double click on the device name.

After selecting the device the following screen will appear.

Figure 12 PSY1 connecting

It states the following:

(1) that the software is *"connecting to the PSY"*
(2) Battery Voltage is 3.89 V prior to the software actually connecting
(3) And the device is located on COM 4.

You are now connected to the PSY1 Stem Psychrometer. You will see the Instrument Information Section filled with the configuration data of the instrument you are connected to. This data is read directly from the instruments configuration held in non-volatile RAM.

The instrument is now ready to be used. The configuration can be modified, logging interval set, Data downloaded or readings performed manually.

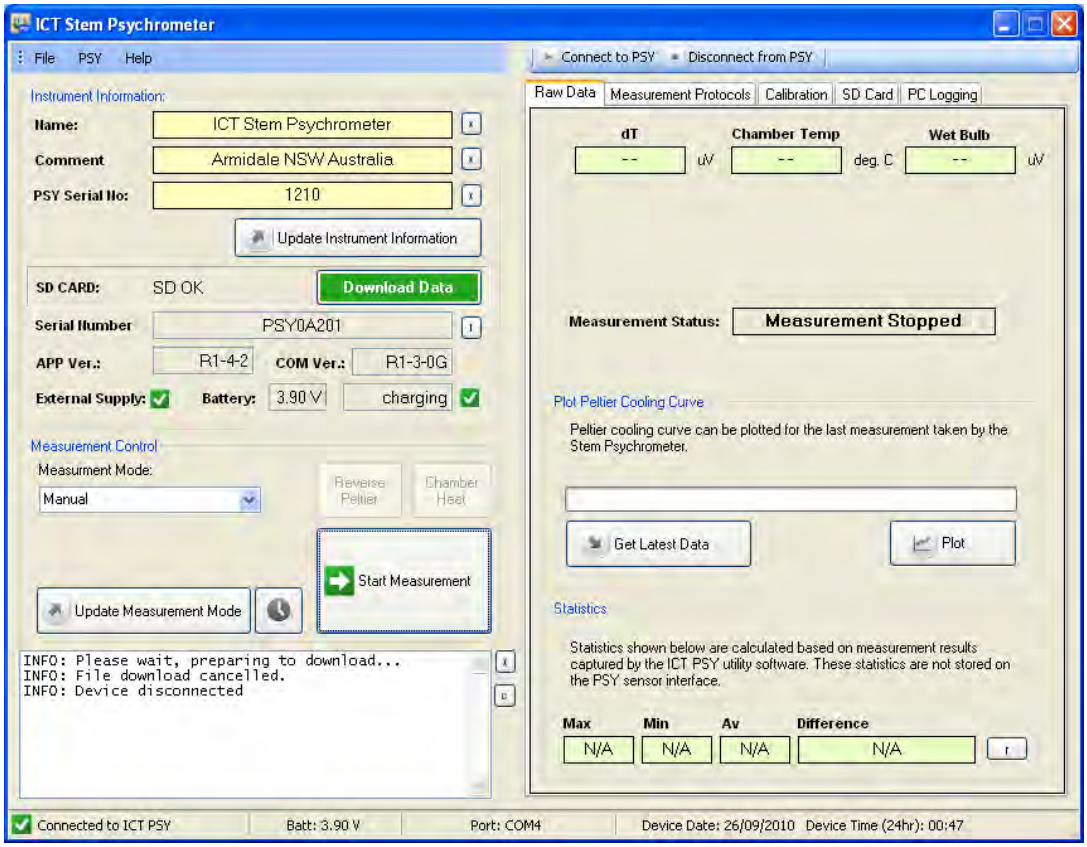


Figure 13 The PSY1 Graphical User Interface connected to an instrument

13.3 MCC1 - RF Modem:

13.3.1 RF Connection Type

Drop down the ***"Connection Type"*** box (located in the bottom left hand corner of the screen) and select RF (Radio Frequency).

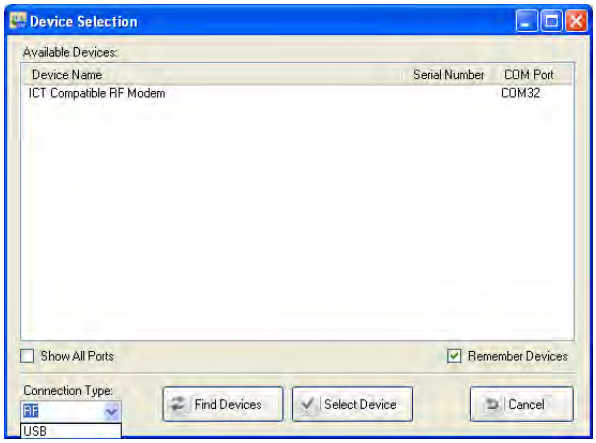


Figure 14 Device Selection Window – Connection Type RF

If an MCC – Multi-Converter RF Modem is connected to the PC it will automatically be displayed in the list of "Available Devices" showing the COM port it has been automatically allocated by the Windows OS.

13.3.2 RF Find Devices

If the message ***"No compatible devices found" is displayed*** before proceeding to click the ***"Find Devices"*** icon please check the following:

(a) The MCC is connected via a USB cable to the PC
(b) The LED of the MCC is lit up to confirm the MCC is functioning.
(c) The ***"Connection Type"*** has been changed from USB to RF
(d) Then click the ***"Find Devices"*** icon

Figure 15 Device Selection Window

13.3.3 RF Select Device

You can now select the device "ICT Compatible RF Modem" by clicking on it with the mouse to highlight the device then click, on the ***"Select Device"*** icon. Alternatively, you can simply double click on the device name.

13.3.4 RF Device Chooser

Clicking on the ***"Select Device"*** icon will open the ***"RF Device Chooser"*** List

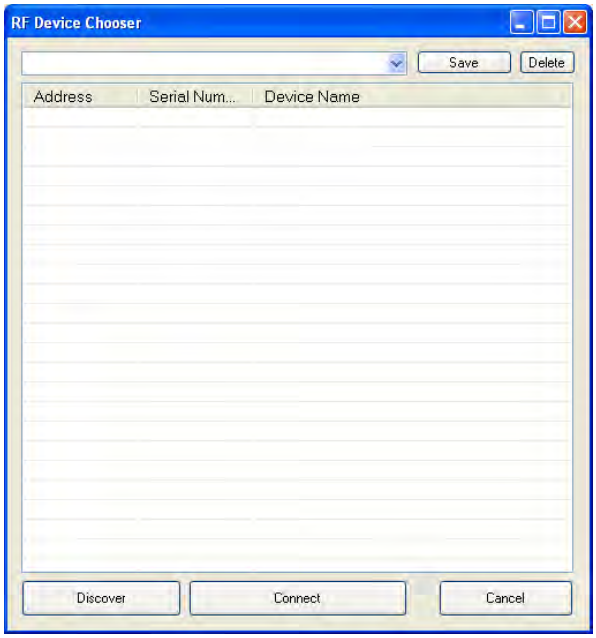


Figure 16 RF Device Chooser Window

The list will initially be blank until a search has been performed for instruments within range (approx. 250m).

NOTE 23 Range is strictly line of sight and will vary depending up ambient conditions that affect signal strength such as atmospheric moisture and density of foliage.

13.3.5 RF Discover

Click on the ***"Discover"*** icon to begin the ***"Device Wake Up Routine"***

Figure 17 RF Device Chooser Window – attempting to wake up devices within range

Each PSY1 instrument has an integrated radio transceiver and antenna. They are configured to wake up every 10 seconds for a millisecond to send a short signal.

13.3.6 RF Device Wake Up Routine

During the ***"Device Wake Up Routine"***, the RF Modem scans the 2.4 GHz frequency for a period of 20 seconds, "listening" for a signal from any PSY1 Stem Psychrometers that may be within range. As each unit only emits a signal every 10 seconds an initial wait time of 20 seconds is required to ensure all instruments within the area have had time to respond within the discovery window.

Figure 18 RF Device Chooser Window – Discovering devices within range

13.3.7 RF Search for more Devices

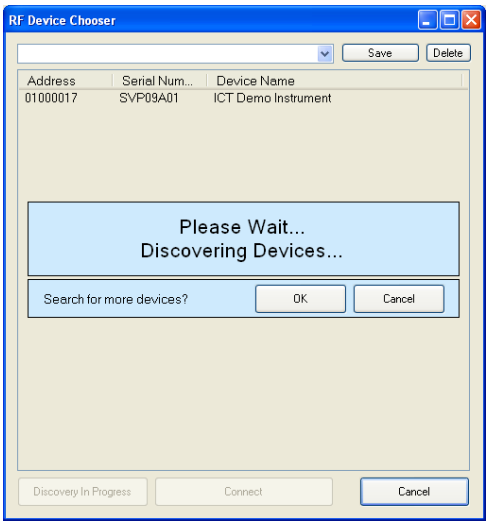


Figure 19 RF Device Chooser Window – Search for more Devices?

If a known instrument has not been discovered during the initial 20 second poling routine the GUI software allows you to continue to search for more devices, to do so click the "OK" icon when asked, **"Search for more Devices?"**

If all devices have been discovered click the “Cancel” icon to gain access to the list of devices found.

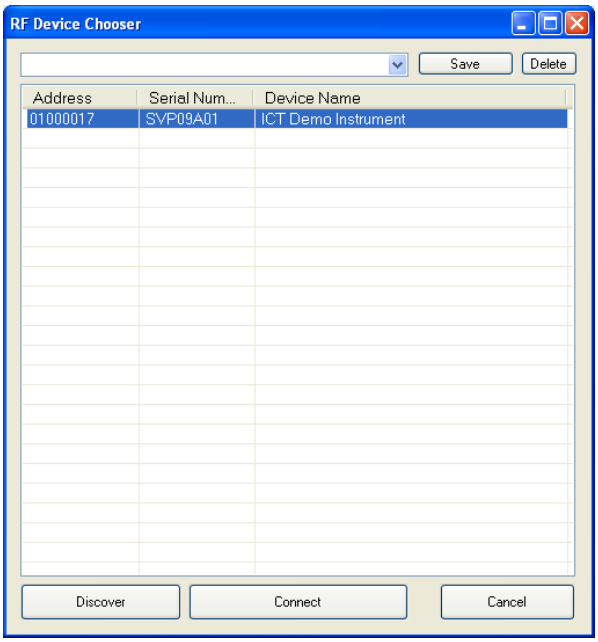


Figure 20 RF Device Chooser Window – displaying the devices within range that have been discovered

13.3.8 Saving discovered devices as a group

Once the discovery routine has finished polling all compatible devices, a list of all compatible devices found will be displayed. Each instrument displayed in the list can be individually selected and you can connect to it either by highlighting the device and clicking on ***“Connect”*** or double clicking on the device name itself.

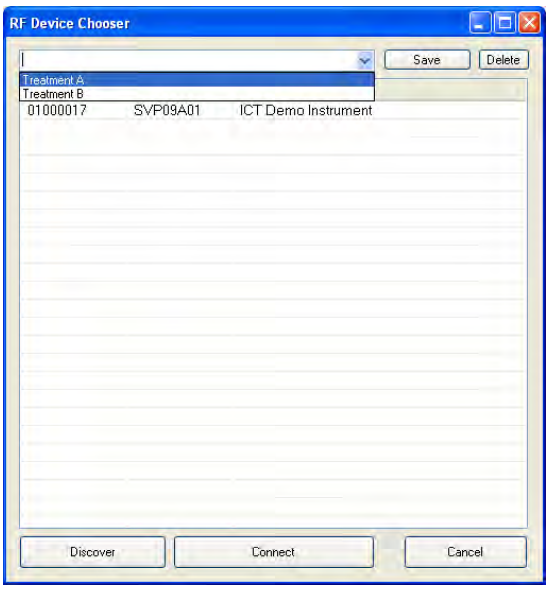


Figure 21 RF Device Chooser Window – Save Groups Option

To eliminate the need to find devices each time you run the software you can create groups of instruments. Once a group of instruments are discovered allocate them a name such as *"Treatment A"* and click on the *"Save"* Icon. Next time you click on *"ICT Compatible Modem"* you can chose to drop down the group of sensors you wish to download as the discovery routine has already been done and remembered by the GUI Software. Each instrument displayed in the list can be individually selected and you can connect to it either by highlighting the device and clicking on *"Connect"* or double clicking on the device name itself.

After selecting an instrument or, an individual instrument from within a saved group, the following screen will appear.

Figure 22 Connecting wirelessly through the MCC1 Radio Frequency modem to a PSY1

It states the following:

(1) that the software is Establishing RF Link
(2) *then "connecting to the PSY"*
(3) Battery Voltage is 3.89 V prior to the software actually connecting
(4) And the device is located on COM 32.

You are now connected to the PSY1 Stem Psychrometer wirelessly through the MCC1 Multi-Converter RF Modem. You have all the same functionality and speed of a direct physical connection via a USB cable, plus the freedom to move around the area beyond the physical reach of the instrument.

You will see the Instrument Information Section filled with the configuration data of the instrument you are connected to. This data is read directly from the instruments configuration held in non-volatile RAM.

The instrument is now ready to be used. The configuration can be modified, logging interval set, Data downloaded or readings performed manually.

14 LED's

The instrument has two sets of red & green Light Emitting Diodes (LED's). These diodes are programmed to give specific flash sequences to indicate different states of operation of the instrument.

14.1 Power Circuit LED's

The main set of LED's are connected the power circuit of the communications board and are visually accessible via a light tube adjacent to the communications access port. They indicate whether the board is awake and whether the battery is charging.

14.1.1 LED Flash Sequence Definitions

14.1.1.1 Green LED

Usually indicates device is on / not in a low power state

14.1.1.2 Red LED

Usually indicates device battery is charging.

14.1.1.3 Instrument Start-up

Green and Red LEDs blink alternately several times (this is also to indicate a successful reset). Green LED then turns on indicating that the board is powered on. Red LED may turn on depending on whether the device is charging. After a few seconds, the Green LED should blink, indicating that it `has successfully initialised. After a timeout (depending on comms activity between the two boards), both LEDs will turn off, indicating that the unit has entered a low power state.

14.1.1.4 Instrument Running

Every 10 seconds, the green LED will blink for a short amount of time. This indicates the board has powered on and is looking for a RF signal (generally a wake up signal). If a signal is received, it will stay on for a little longer to see if the messages are wake up messages or messages specifically for that unit. If so, the Green LED will stay on for another 30s-1minute.

14.2 USB Communication LED's

The second (and smaller set of LED's are connected to the USB communications port. They are located inside the communication port and are not visible if the communications port is closed. The USB LEDs tell you activity on the COM's lines when a USB cable is connected or wireless comms via the MCC1 Radio Modem.

14.2.1 Red LED

Usually indicates data received. If the red LED is blinking occasionally and green one isn't that means that the software is trying to communicate with the board, which for some reason isn't responding. You should generate a Debug File to check the integrity of the USB Comms Port.

14.2.2 Green LED

Usually indicates data sent.

14.3 Device Firmware

When using the Device Firmware Update software (otherwise known as a Boot Strap Loader or BSL) to update the application board, the Red LED will continuously blink (regardless of what battery charging is doing). The board should not be powered down while the Red LED is blinking because it will halt the BSL process, and the microprocessor will not have been programmed correctly.

While performing BSL updating the generic comms board, the LEDs should be off, but could be in any state, because the microprocessor is being loaded with firmware, and is not controlling the LEDs.

14.4 Power down:

When the power button is pushed, either a Green LED or Red LED will blink while you are holding the power button. If the Green LED blinks, the board will not switch off when you let go of the power button. This is most likely because it is powered externally, and cannot shut down. If the Red LED blinks, the board is ready to be powered down. Letting go of the power button will start the power down sequence, which will result in both LEDs blinking and fading out until the board is off*.

Note 24 If power is applied to the external inputs during the power down sequence, power down is aborted and the unit will reinitialise.

15 Measurement Protocols

The Measurement Protocols tab is where the majority of the configurations settings for the PSY1 are made.

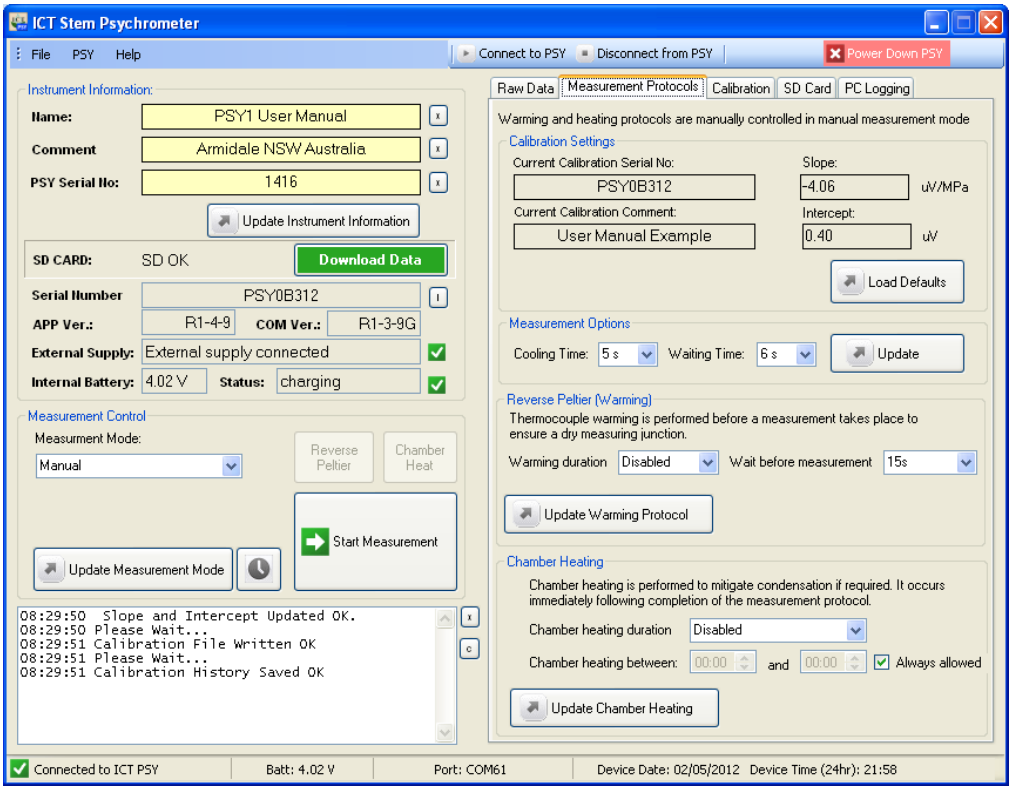


Figure 23 The Measurement Protocols are situated on a dedicated tab in the software

15.1 Calibration Settings

This is an instant reference of the calibration slope and intercept that will be applied to the raw Psychrometric Wet Bulb Depression to convert it to Water Potential in MPa. The actual calibration file is stored on the MicroSD card using the four digit serial number of the psychrometer chamber that was calibrated.

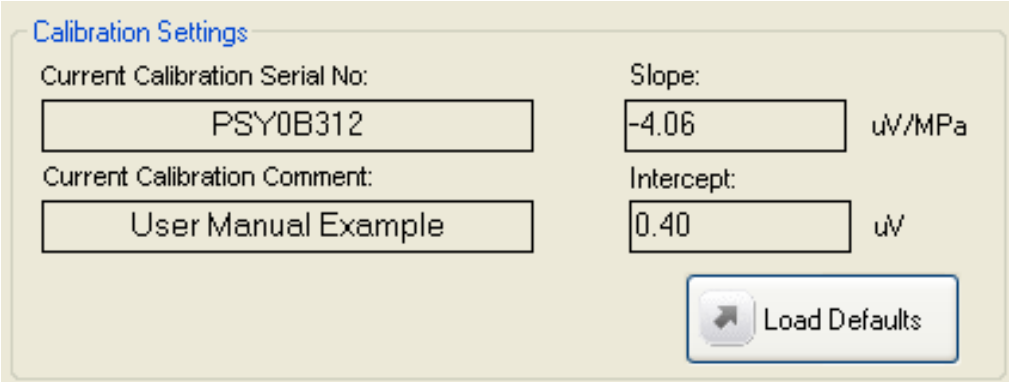


Figure 24 Summary listing of the calibration settings applied to the PSY1

The calibration file contains the serial number of the PSY1 that was used to perform the calibration along with a user comment to reference the time or reason the calibration was performed. This information is read from the cal file and displayed in this window.

After calibration of a psychrometer the new calibration slope and intercept will automatically be updated in this field. Before it is written to firmware the user is prompted to accept or decline the new slope & intercept. The calibration process is covered in detail in the Calibration section of the manual.

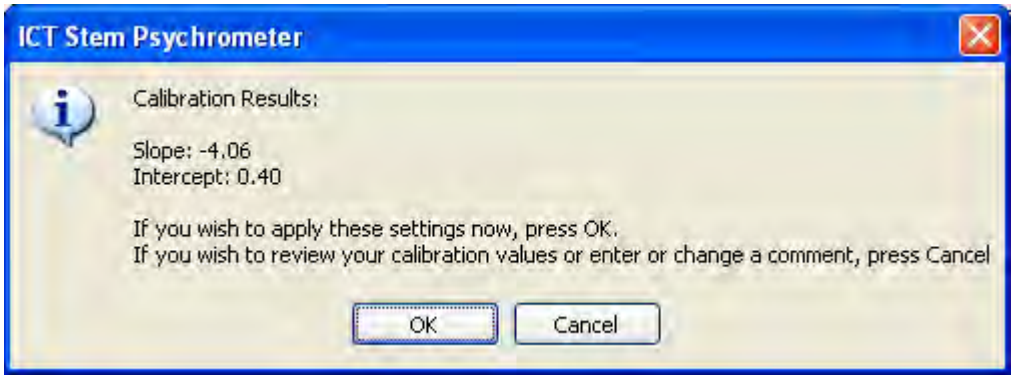


Figure 25 Confirmation Window before writing PSY1 Calibration settings to firmware.

15.2 Measurement Options

Measurement Options deal specifically with the duration of the Peltier Cooling Pulse and sampling point at which the Psychrometric Wet Bulb Depression is read after the end of cooling. When a change is made to either parameter it is necessary to confirm this change and write it to firmware by clicking the Update icon. If the change is not updated, then no change is made to firmware and the next time the software is opened or the instrument connected, the previous settings will remain.

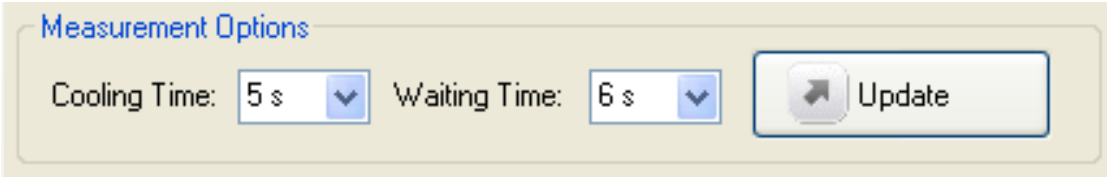


Figure 26 Drop down boxes to adjust the duration of the Peltier cooling time and sampling point

15.2.1 Cooling Time:

The length of the Peltier cooling pulse will determine the volume of water that is condensed onto Thermocouple-C. A short cooling time will result in a small volume of water that will quickly evaporate back into the atmosphere of the chamber. Conversely, a long cooling time will condense a large volume of water, and slowly evaporate back into the atmosphere of the chamber.

The volumes of water and the times taken to change from liquid to vapour phase will be determined by the vapour pressure within the chamber which is in equilibrium with the plant. It should be

understood that as conditions become more negative it may be necessary to increase the cooling time to ensure a sufficient volume of water is condensed onto Thermocouple-C to generate a Psychrometric Wet Bulb Depression. If insufficient water is condensed in a “dry” environment (very negative water potentials) the cooling effect and hence the plateau will not remain for the necessary 6 seconds in order to record a measurement, and instead generate a false reading, or most commonly no reading at all.

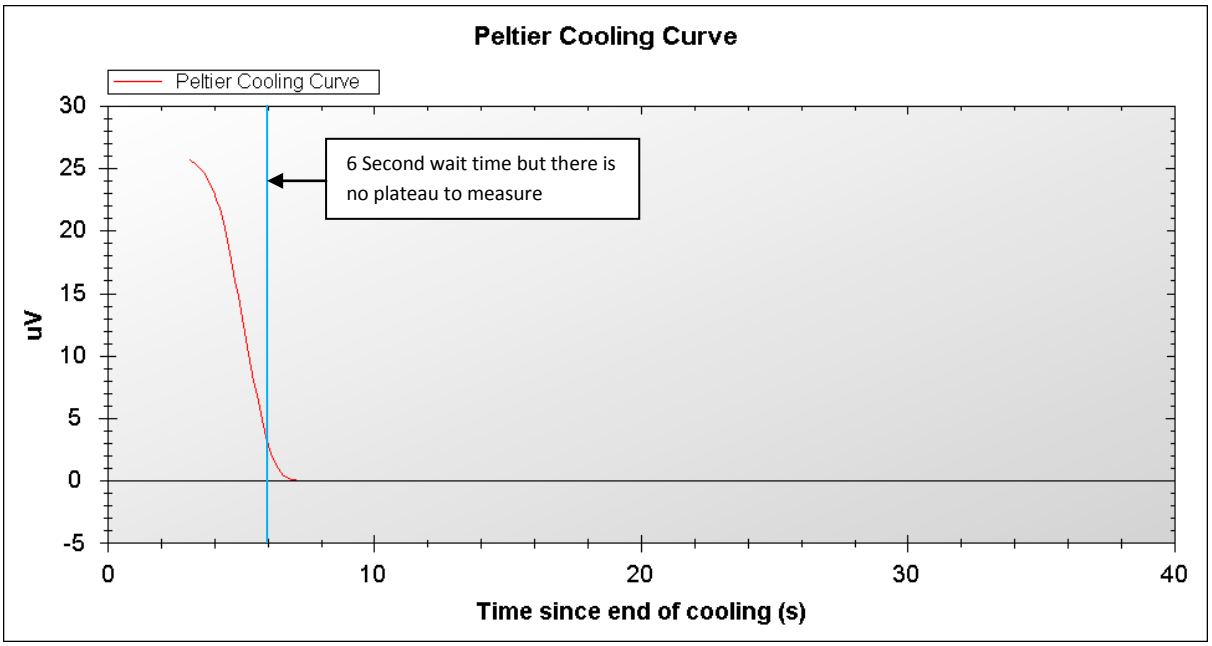


Figure 27 Peltier cooling curve with insufficient cooling time

Conversely, if the cooling time is too long in a “wet” environment (values close to zero MPa) then it may be that the time interval for absorption of the condensed water back into the atmosphere is so long that the minimum 10 minute logging interval cannot be used. This situation can be identified by reviewing the Peltier cooling pulse. If the temperature of Thermocouple-C is failing to return to zero by the end of the 40 second sampling window, then the logging interval should be reviewed.

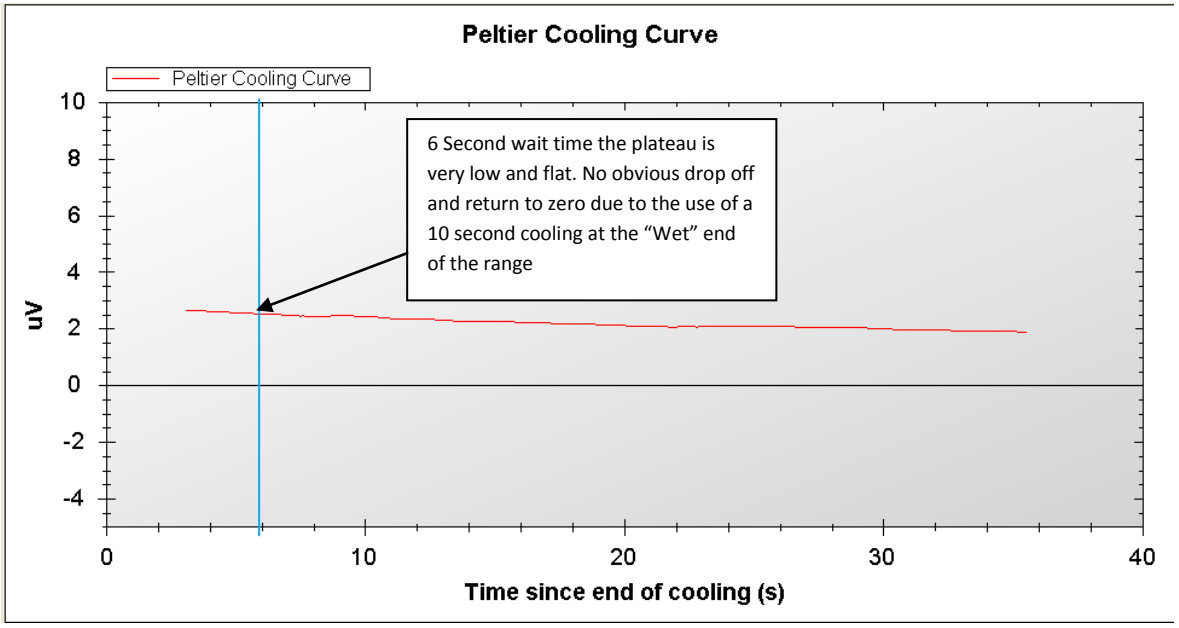


Figure 28 Peltier cooling curve with an excessive cooling time relative to the water potential of the sample resulting in a much longer time required for Thermocouple-C to return to zero reference. This sample was taken on *Sequoia sempervirens* (Coast Redwood) and the measured water potential (-0.76 MPa) was simultaneously verified against a Scholander pressure bomb (-0.73MPa)

It is important to note that the length of the Peltier cooling pulse does not affect the measured water potential. It will only affect the duration of the Psychrometric Wet Bulb depression. This is best demonstrated by performing a calibration measurement using a 1.0 Molal solution on a filter paper placed in the calibration lid. Place the PSY1 in Manual mode and set the Peltier cooling time to 5 seconds. Then commence a reading. For a clean psychrometer the response will be in the range of 19 µV and the duration will be approximately 10 seconds before a sharp drop back to zero reference.

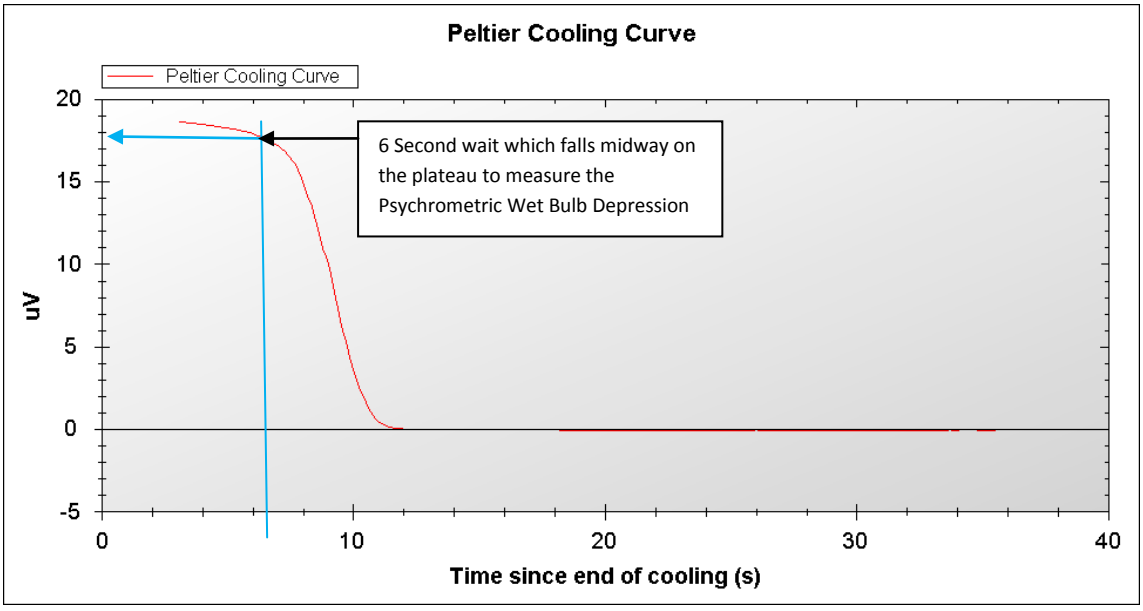


Figure 29 Peltier Cooling Curve produced with a 5 second cooling time the plateau extends to 10 seconds before returning to zero reference.

Now wait a few minutes (preferably 10 minutes to allow the vapour pressure to return to equilibrium within the chamber) and repeat the measurement, but this time increase the cooling time from 5 seconds to 10 seconds. There will be negligible (if any) difference in the measured µV output of the Psychrometric Wet Bulb Depression, but the Peltier cooling curve will be approximately twice as long as the previous measurement extending to approximately 20 seconds before sharply dropping and returning to zero reference. This clearly demonstrates the Psychrometric principle that the Wet Bulb Depression is the temperature at which water condensed on the Thermocouple-C cools the thermocouple as it evaporates. It also shows the independence of the measurement to the volume of water condensed on the Thermocouple, yet the significance this can have on the temporal logging interval. If measuring well hydrated plants in the "wet" end of the plant water potential range (close to zero) it may not be possible to measure at 10 minute logging intervals, instead 15 to 30 minute intervals may yield better results.

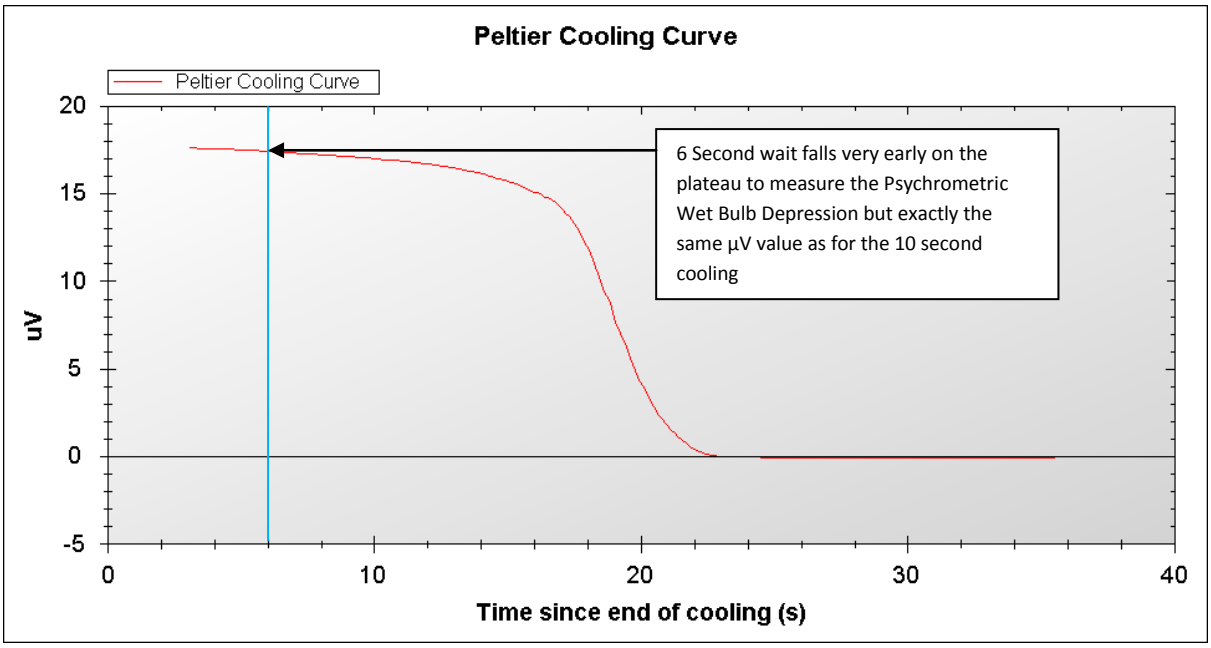


Figure 30 Peltier Cooling Curve produced with a 10 second cooling time the plateau extends to almost 20 seconds before returning to zero reference.

NOTE: 1 do not attempt to repeat manual measurements sequentially without allowing equilibration time, typically 10 minutes between each reading. It is necessary to allow vapour pressure between the chamber and the stem to return to equilibrium after having first condensed water from the atmospheric vapour of the chamber and subsequently allowing it to be evaporated it back into vapour. Failure to allow this time will result in disequilibrium between the atmosphere and the stem, create a compounding affect in the measurement and seemingly the sample will continue to become wetter or less negative (closer to zero) which is not a true representation of the plant's water potential.

15.2.2 Wait Time:

The Wait time is an empirically derived interval. It has been determined over years of empirical observations and comparisons against sophisticated algorithms to fit tangents to the curve of the Peltier cooling curve. Whilst such sophisticated algorithms are possible these tend to introduce variability into the results that do not appear by opting for a fixed time period upon which to always make the Psychrometric Wet Bulb Depression measurement.

15.3 Reverse Peltier (Warming)

The reverse Peltier Current or "warming" is used to dry off any microscopic beads of water that may remain on the thermocouple following a measurement. You can automate this to provide a user defined temporal interval for warming of Thermocouple-C prior to taking a measurement. There is also a user adjustable wait time which prevents a measurement from being taken to allow the thermal gradients (small though they are) to dissipate from the chamber before the next measurement.

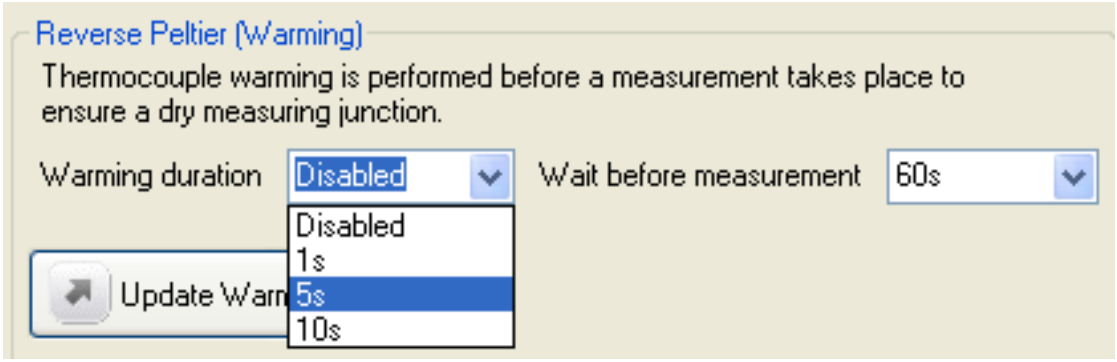


Figure 31 Reverse Peltier (Warming) settings

15.4 Chamber Heating

Under environmental conditions that favour undesirable temperature gradients (i.e., the chamber is colder than the stem) the heater can be used to mitigate these problems. A 12 V (DC) resistive heater is integrated into the back of the chamber and controlled by the PSY1. The chamber heater can be set to automatically turn on immediately following the completion of a measurement. The duration of the chamber heating can be set by selecting the desired time period from the drop down box. The exact duration for every installation will be specific to the ambient conditions and the plant being monitored. It may be necessary to trial a range of chamber heating durations between the ranges of 15 seconds to 2 minutes until the ideal protocol for the prevailing conditions is determined.

Note 25 the appropriate chamber heating protocol is one which maintains conditions such that condensation will not occur on the chamber walls (i.e. the chamber is warmer than the sample).

Chamber heating can be continuously employed, but this has the potential to cause artificial drying of the stem if employed when undesirable temperature gradients are not present. As a broad guideline the most likely period for condensation to occur inside the chamber, due to the chamber being colder than the stem, is between 5:00AM to 10:00AM.

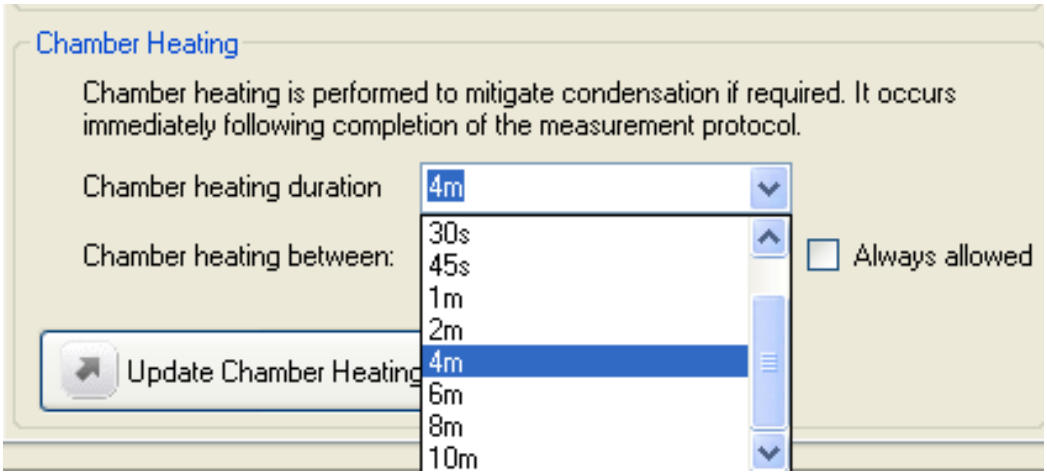


Figure 32 Chamber Heating Duration drop down box, heating duration can be set from 15 seconds to 10 minutes

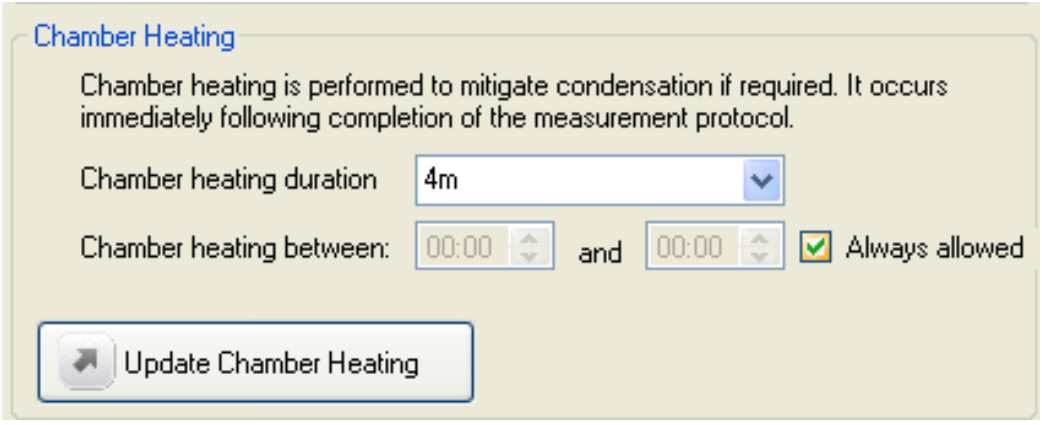


Figure 33 Chamber Heating can be set to be always active after each measurement

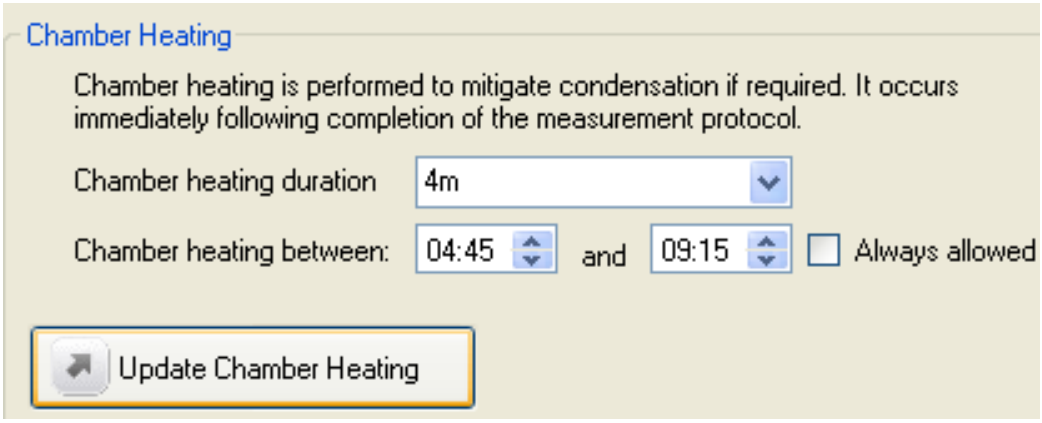


Figure 34 Chamber Heating should be set only to operate within the early hours of the morning when conditions are assessed to be most conducive to condensation.

Note 26 the Live Mode function can be used to evaluate the heat ring down in the chamber to empirically set the temporal interval between heating and measurements for each installation. Set the PSY1 to Manual Mode and activate Chamber heating. Set the heating duration and update these settings to firmware. Then start Live Mode logging and set the logging interval to 1 second. Now when a manual is made the dT, Chamber Temperature and Thermocouple-C values will be logged every second during and after the measurement until logging is stopped. This will record the effect of chamber heating on the Thermocouple output and the period of time required for this effect to dissipate can be determined. This data can then be used to develop the specific chamber heating protocol for the experiment.

16 Calibration

Calibration of the stem psychrometer is accomplished by preparing a range of standard sodium chloride (NaCl) solutions of known molality in the range 0.1, 0.2, 0.3, 0.4, 0.5 and 1.0 Molal. The exact NaCl volumes per 50 ml volume of water are provided in the Appendix Preparation of Calibration Solutions. These concentrations are derived from the work of Lang, A.R.G, Osmotic Coefficients and Water Potentials of Sodium Chloride Solutions from 0 to 40°C 1967. *Australian Journal of Chemistry*, **20**, 2017-23. (Appendix Osmotic Coefficients and Water Potentials of Sodium Chloride Solutions). This range of concentrations correspond well to the typical range of water potentials experienced by crop plants and trees (-0.642, -0.915, -1.368, -1.823, -2.281 and -4.640 MPa).

Saturated filter paper disks (Watman's No.1) are used for calibration purposes. These are supplied by ICT already cut to the correct 6 mm diameter size required for the calibration lid holder. Replacements are conveniently obtained using a standard paper punch. Measurement of thermocouple output in the suggested range is essentially linear at a given temperature.

Note 27 always use a freshly made NaCl calibration solutions using the "recipe" as per Appendix Preparation of Calibration Solutions. It is recommended for those making calibration solutions for the first time to watch VIDEO 16 – Making Calibration Solutions

16.1 Pre-Calibration Cleaning

The slope and intercept will be different for each psychrometer as the thermocouples are hand made using a very thin 25 µm wire. The thermocouple surface will have a natural variation that may have more or less dimpling providing different physics for the condensation of water. This is further impacted by the cleanliness of the thermocouple hence, it is imperative that the chamber is cleaned prior to calibration.

NOTE 28: When the chambers are cleaned, and calibrated at 25°C using fresh Molal calibrations solutions the calibration protocol reliably returns R^2 of 0.999 to 0.9999.

It is advisable to enhance the vapour seal between the faces of the chamber and the calibration disk holder with a small amount of silicon grease. It is also helpful if calibration is carried out in a stable thermal environment or temperature controlled chamber.

Watch a demonstration VIDEO 17 – Sealing the Calibration Lid to the Psychrometer to perform a calibration measurement

16.2 Calibration Temperature

Calibration is usually done at, or corrected to, 25 C. Temperature correction for Psychrometric measurements is given by:

$$\text{Corrected Reading} = \text{Reading}/(0.027T + 0.325) \quad \textbf{Equation 3}$$

Where: T is chamber temperature in C.

The calibration routine should be carried out in a temperature controlled chamber if possible. However, if you can only manage crude temperature control, then this is often worse than none at all. Rapid cycling of temperature caused by heating and cooling systems initiates transient gradients in the instrument and confound accurate calibration procedures. The relatively stable temperature of a large room is preferable. Corrections for ambient conditions can be made using the formula above.

16.3 Calibration Chamber

Here is a simple and effective means to achieve stable temperature control. You will require a good quality circulating water bath, preferably with proportional control of water temperature. This eliminates the typical "sawtooth" temperature control of less sophisticated baths. Circulate the water through a flexible copper tube (1-2 cm diameter and 2-3 m long) which is then coiled and placed inside a box close to the inside edges. Construct the box of dense styrofoam (eg. 5 cm. thickness, Styrofoam SM) and line all inside surfaces with a reflective foil (eg. aluminium foil). The dimensions of the box should accommodate the number of psychrometers you intend to calibrate as well as one or two small electric fans to facilitate air mixing. Internal dimensions of approximately 50x50x50 cm are appropriate. Suspend a light plastic grid in the centre of the box to serve as a platform for the psychrometers. This allows air movement around the instruments and eliminates temperature gradients from conductive surfaces. Normal equilibration times for salt solutions are quite brief but it is safest to allow between 30 to 60 minutes for each solution to equilibrate depending upon how intensively the psychrometer was handled while loading the calibration solution.

Watch a demonstration VIDEO 18 detailing the components used in the construction and use of a simple calibration chamber for psychrometers

16.4 Calibration Protocol

Prior to attempting a calibration of the psychrometer for the first time it is recommended that you watch the VIDEO 19 calibration protocol that clearly details all the practical steps involved in the successful calibration of the PSY1 Stem Psychrometer. An additional Video 20 demonstrates the software calibration function to initate a measurement and process the calibration data.

The calibration routine is designed to be semi-automated and all inclusive within the PSY1 software, from making measurements of calibration solutions to plotting the data, generating a slope and intercept and storing the calibration in the firmware of the PSY1 Instrument for real time data processing.

16.4.1 Start Calibration

To begin a calibration, start by opening the software and connecting to the PSY1 instrument. Then click on the Start Calibration button, the software is now in calibration mode and you will only be able to perform a calibration.

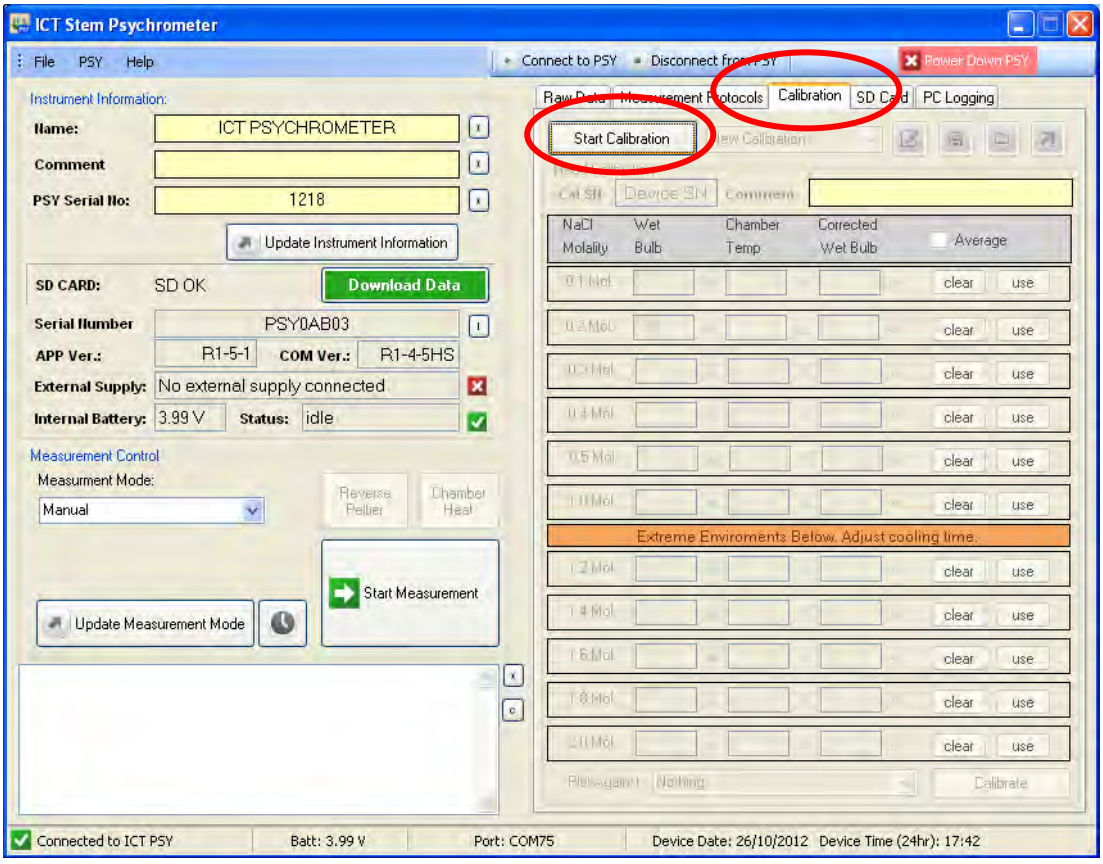


Figure 35 to begin a calibration click the Start Calibration icon on the Calibration Tab

Note 29 a calibration can only be performed in Manual mode. If you attempt to "Start a Calibration" while in Live Mode or while the instrument is logging an error message is displayed.

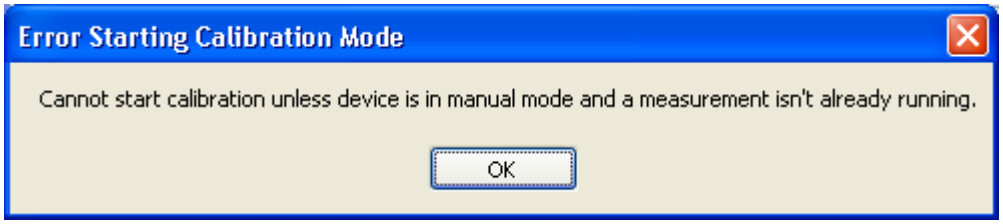


Figure 36 Error message displayed if calibration mode is attempted when the instrument is not in Manual Mode

16.4.2 Loading the Calibration Filter Paper

Place a known calibration solution on a filter paper inside the calibration lid of the Psychrometer. Place the Psychrometer into an isothermal calibration chamber ideally set and regulated to 25°C and leave for at least 30 minutes to preferably 1 hour to equilibrate before making the measurement.

NOTE 30: It is advised to start with a 1.0 molal solution to test the integrity and cleanliness of the thermocouple. See diagnosing a dirty thermocouple. Run a manual measurement on this solution first and plot the Peltier cooling curve before starting the calibration. If the plateau is not in the general range of 17-20 µV for about 10 seconds then falls sharply to the zero reference and remains there then it is advised that the psychrometer be cleaned before proceeding with the calibration. Always good to know this before performing a calibration!

16.4.3 Selecting the Calibration Range

Click on the "use" button corresponding to the calibration solution you have placed in the psychrometer calibration lid. This measurement range is now active denoted by the subtle change in colour of all the input cells in that row.

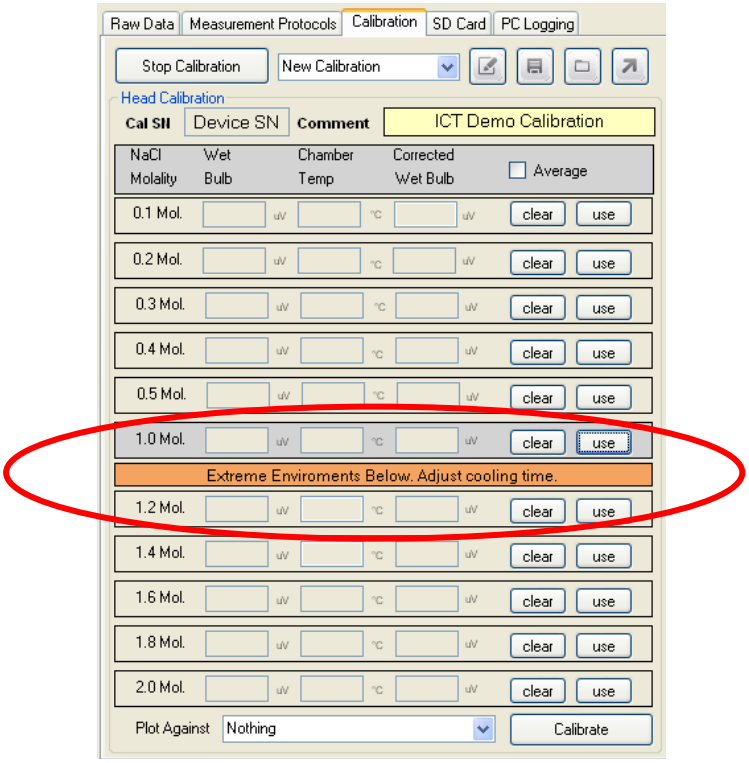


Figure 37 selecting the calibration range

16.4.4 Start Measurement

Click the “Start Measurement” button, and a measurement is commenced.
Upon completion of the measurement the fields will automatically be populated with the relevant data;

i. Wet Bulb Depression;
ii. Chamber Temp;
iii. Wet Bulb corrected to 25°C.

Remove the calibration solution and replace it with the next solution.
Repeat this procedure for at least 3 calibration solutions. The software is locked to ensure a minimum of any 3 points are recorded satisfy a calibration. 6 points are preferred.

NOTE 31: if you check the Average box you will be able to take multiple measurements at each cal solution and automatically average the values for use as the data point for that cal solution on the graph. Allow at least 10 minutes between replicate readings. Whilst this option is provided if readings show sufficient variation to warrant using an average function it is recommended that you review your calibration procedure and clean the psychrometer.

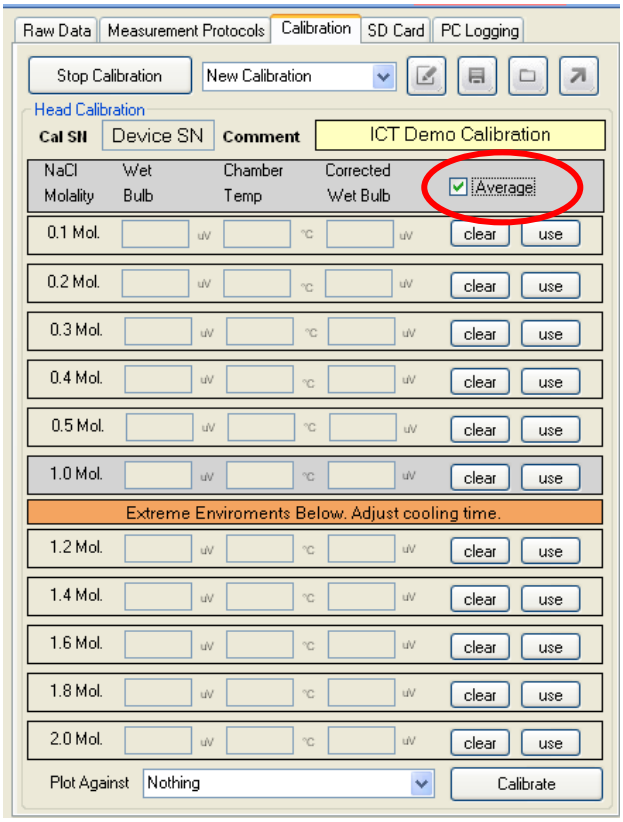


Figure 38 tick the average box if you wish to make multiple measurements at each calibration solution and average them.

16.4.5 Generate Calibration Curve

When at least a minimum 3 data points have been measured, click on the Calibrate button at the bottom of the screen.

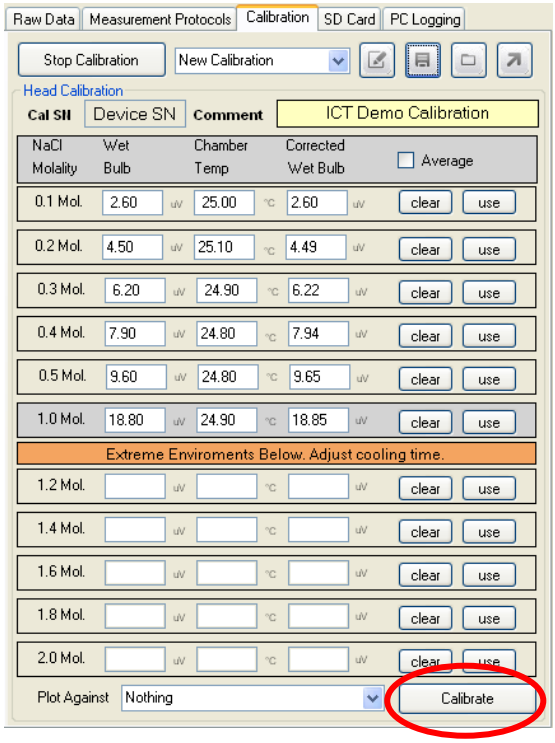


Figure 39 click calibrate once all measurements have been recorded

The data points will be automatically plotted, a regression line fitted, the slope, intercept and R2 calculated. If the calibration is of suitable accuracy an R^2 of at least 0.999 preferably 0.9999 should be possible and the slope be within the general range of -3.8 to -4.2 µV/MPa and intercept of between 0 to 1 µV

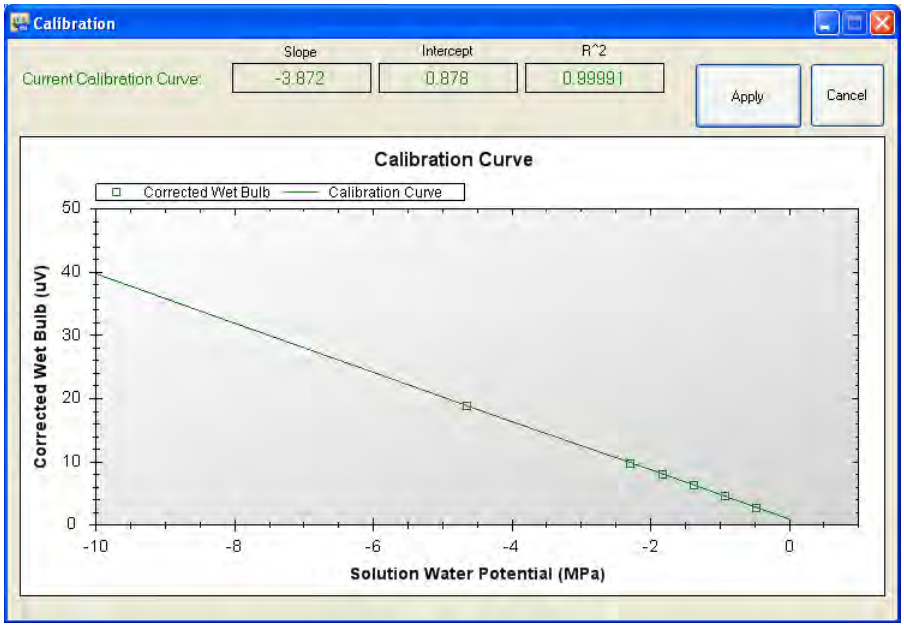


Figure 40 the calibration results are automatically processed and plotted

16.4.6 Write Calibration to Firmware

Click on the Apply icon located in the top right hand corner of the plot. This will automatically write the calibration slope and intercept to the firmware of the PSY1. And take you to the measurement protocol tab and stop the calibration.

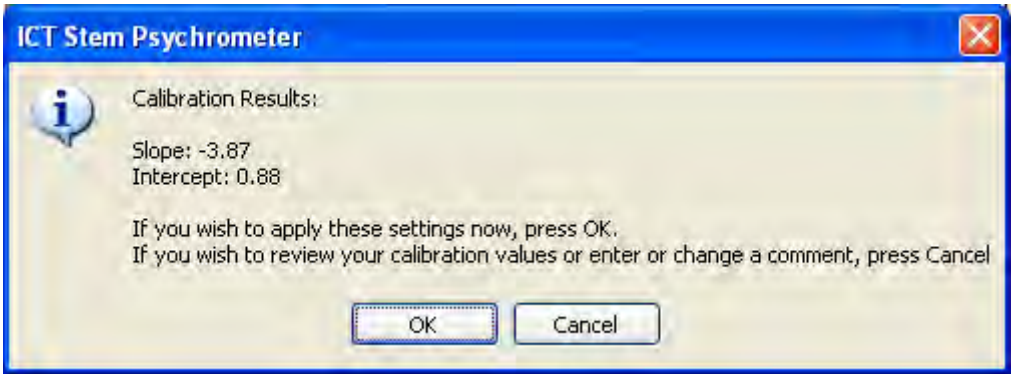


Figure 41 Confirmation Window before writing PSY1 Calibration settings to firmware.

Once the results are confirmed they are automatically written to firmware and displayed in the Calibration Settings on the Measurement Protocols tab. Confirmation that the calibration has been written Ok and the calibration history saved OK is given in the dialogue box. The calibration is now active for this Psychrometer and all measurements made with the PSY1 will use this calibration.

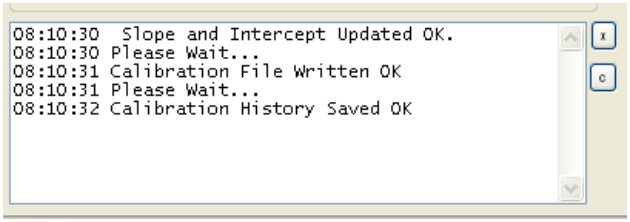


Figure 42 Dialogue box confirmation of calibration change

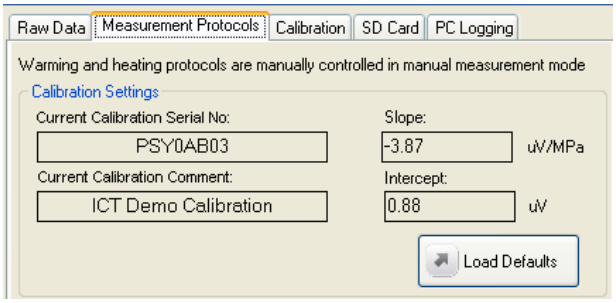


Figure 43 new calibration slope and intercept saved to firmware and displayed in calibration settings

16.4.7 Calibration storage location

The calibration data is saved to a *.rdf calibration file on the MicroSD card using the same name as the number located in the PSY Serial No. Field. This should correspond to the four digit Serial Number of the psychrometer that has been calibrated.

NOTE 32: You should enter the 4-digit serial number of the Psychrometer chamber into this field at the commencement of the calibration and click the update sensor information button.

16.4.8 Loading a Different Calibration

A new or different calibration can be activated by entering a different chamber serial number in the PSY Serial No. field and clicking the update sensor information button. If the calibration file exists on

the MicroSD card it is loaded as the active calibration and all measurements made with the PSY1 will have the raw Wet Bulb Depression data converted to Water Potential (MPa) using this calibration.

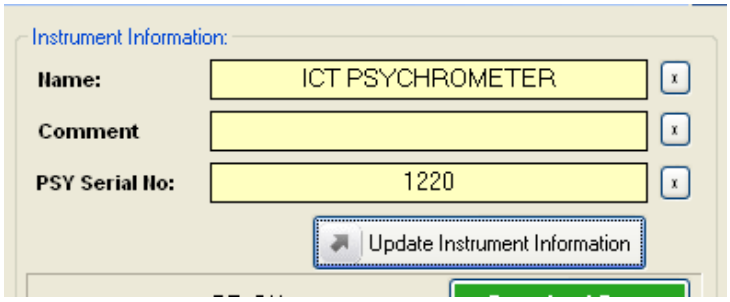


Figure 44 PSY Serial No. field is located in the instrument information panel. Change this number to load a different calibration file.

16.4.9 Default Calibration

The default calibration is a historical average slope and intercept of a small sub sample fo all psychrometers ever made. It is a good general calibration, that will always place the measured water potential within the right range, but it cannot be directly relevant to the specific output of any one psychrometer. If a psychrometer is being used and a calibration file does not exist the PSY1 will be warn the user in the Dialogue box, and the default calibration will be loaded automatically.

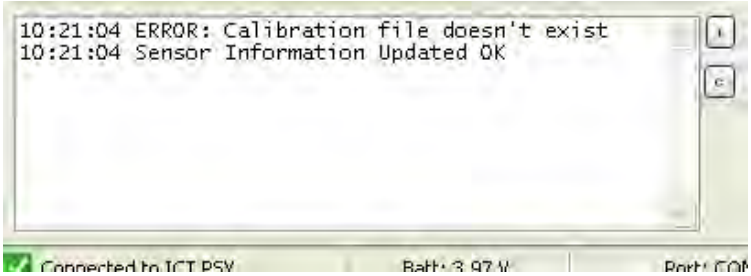


Figure 45 Dialogue Box notification that calibration file does not exist

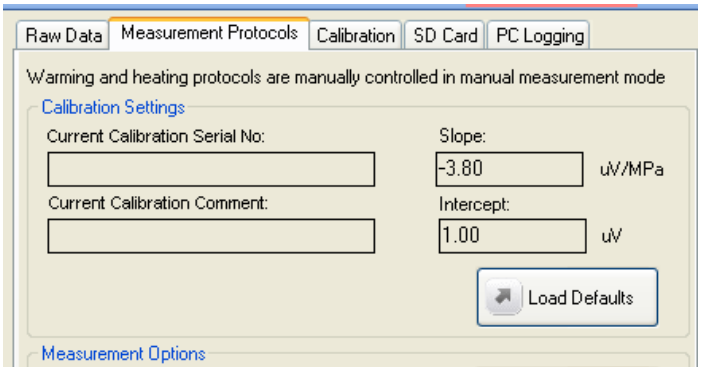


Figure 46 Default Calibration Loaded

Warning 11 – Any data processed with the default calibration will not be accurate. This data can only be considered relative and may display improbable positive water potential values when measurements are made close to zero MPa.

16.5 Checking for calibration drift

Calibration drift should be checked by overlaying the existing calibration file which is stored in the PSY1 against a 3 point check and plotting them against each other every time the chamber is cleaned. This is achieved selecting the new calibration in the top drop down box and the previous calibration in the Plot Against drop down menu at the bottom of the window. Then click Plot.

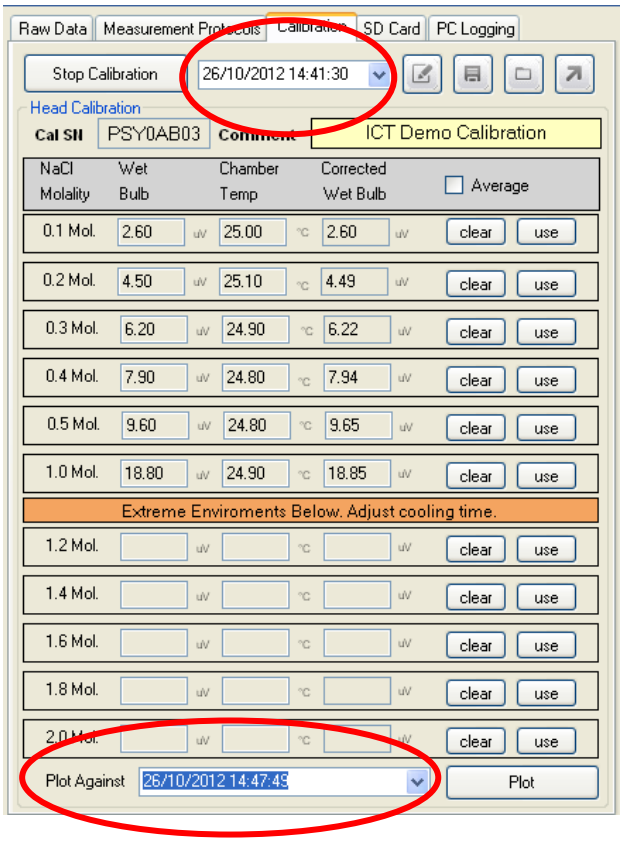


Figure 47 plotting a new calibration against an existing calibration from file

If the calibration curves are significantly different (>5%) then a full 6 point calibration should be performed and saved the firmware of the PSY1 to replace the old calibration. The psychrometer should be cleaned every time it is uninstalled and/or prior to deployment. If the psychrometer has been stored for any length of time, even if it has been stored correctly (with a smear of vacuum grease around the inside of the calibration lid and taped up) to prevent oxidisation of the thermocouples. Oxidisation of the thermocouples will still occur even if only mildly, but it has the potential to influence readings and be the cause of potential errors in calibration even if the chamber is perceived to be "Clean". Always clean the psychrometer before calibration.

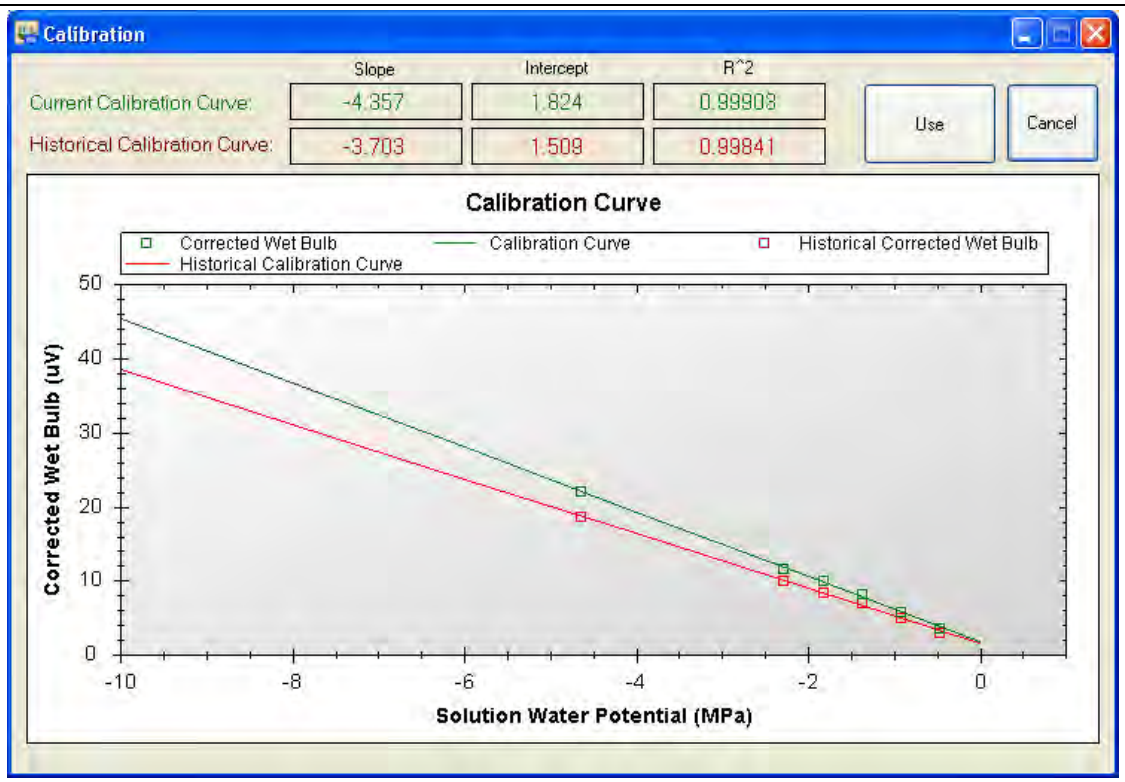


Figure 48 comparison of a new calibration against an existing calibration from file

16.6 Manual Editing of the Calibration

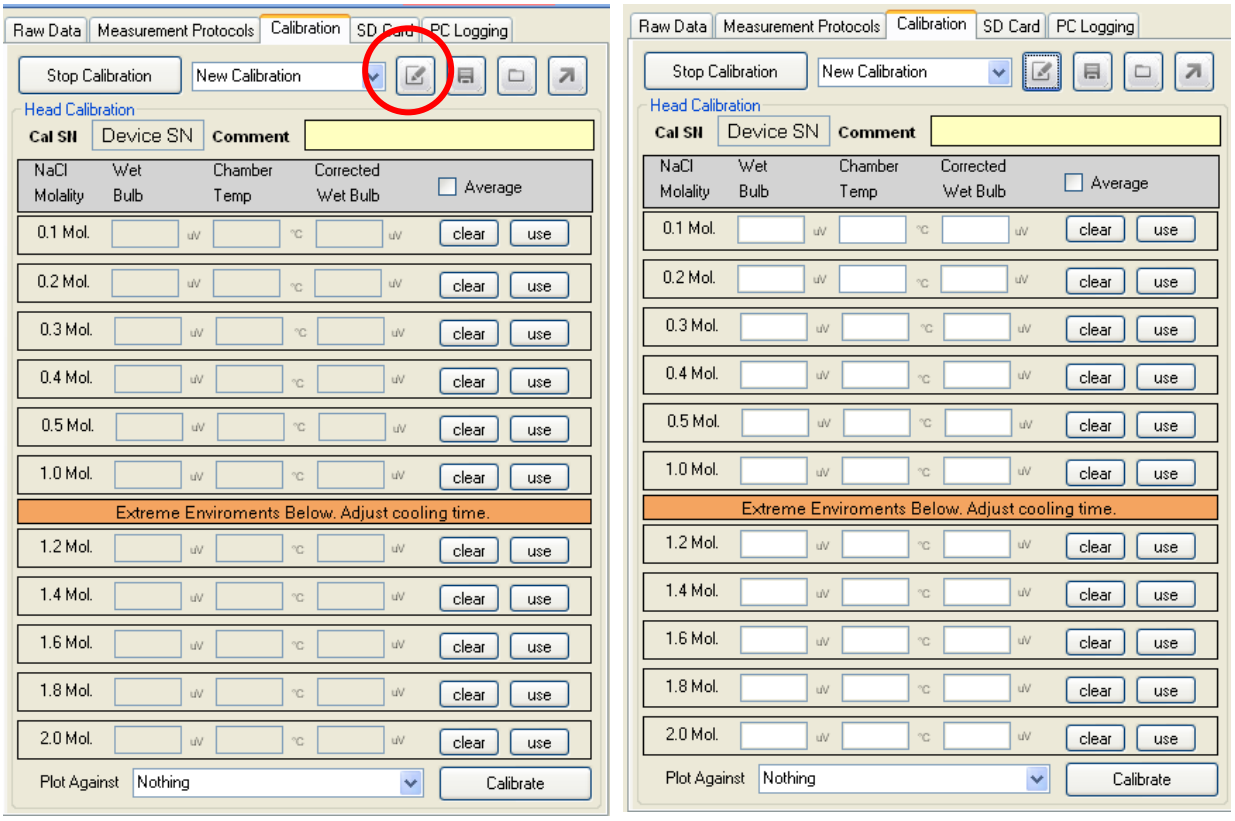
For best results, calibration of a psychrometer should be done within a short period of time, under the same, stable environmental conditions. A full 6 point calibration can take 6 hours allowing a full hour of thermal equilibration time between the measurements of each data point. This may not always be practical so an option to manually edit the calibration is included. The intention of this feature is to allow outlying data points that are of concern to a calibration, to be checked and remeasured without the need to repeat the whole calibration.

Note 33 the integrity of a calibration is imperative to getting good, accurate water potential data. This function should not be used to modify individual points of an existing or old calibration in isolation. It should only be used to check individual points during a full calibration run should there be any doubt over the accuracy of an individual data point.

16.6.1 Edit the Calibration

When a new calibration is started, by default, the calibration input cells are locked, signified by the cells being greyed out (Figure 35 (a)). This is to ensure only directly measured values from the psychrometer can be automatically entered immediately following each calibration measurement.

To edit a calibration you must first "open" the input cells of the calibration interface. This is done by clicking on the "edit the calibration" icon. After clicking the icon the cells change from being greyed out to white signifying that they are open and able to receive manual entries typed from the keyboard of the computer.



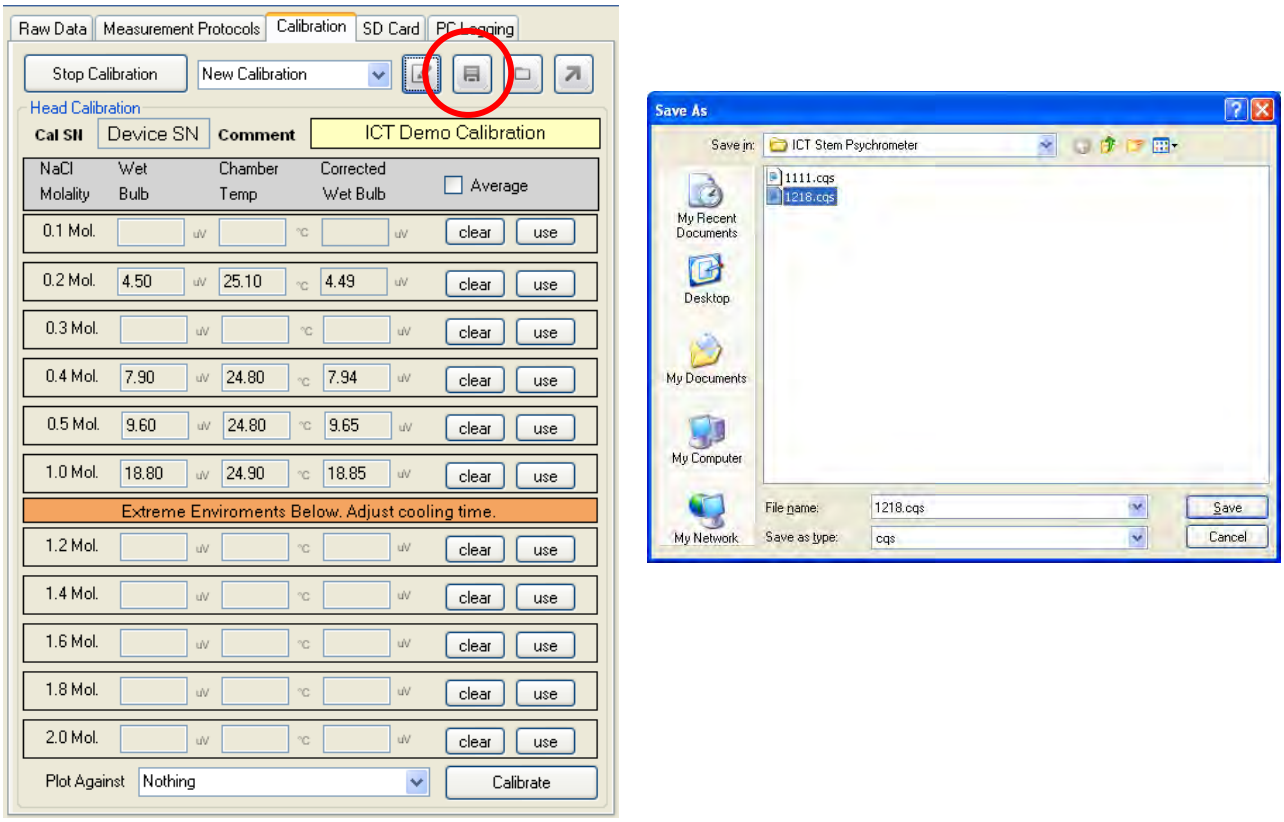
(a) (b)

Figure 49 (a) Calibration input cells are locked until they are opened by clicking the "Edit calibration" (b) cells change colour to white when Open.

16.6.2 Save Current Calibration to HDD

Calibration data can be saved to the Hard Disk Drive (HDD) of the computer at any time by clicking on the Save Current Calibration to HDD icon. This process should be performed after each data point is measured to ensure that no data is lost in the event of a software or OS crash. Clicking on the icon opens a MS Save As ... Window that defaults to the directory C:\Program Files\ICT\ICT Stem Psychrometer*.cqs this directory can be changed to your preferred location.

Note 34 the calibration file should always be saved as the four digit Serial Number of the psychrometer being calibrated. This ensures a tracking reference in the future.



(a) (b)

Figure 50 (a) click the Save Current Calibration to HDD icon to save the calibration data for later retrieval (b) Save As Window to select a preferred location on the computer

16.6.3 Load saved Calibration from HDD

Any calibration file (*.cqs) saved to HDD can also be loaded within the calibration interface. This enables a calibration to be opened, edited, saved as an archived file name or transferred between PSY1 instruments should the psychrometer chamber be used on more than one instrument.

To load a saved *.cqs calibration file, click on the Load Saved Calibration from HDD icon. Clicking on the icon opens a MS Open ... Window that defaults to the directory C:\Program Files\ICT\ICT Stem Psychrometer*.cqs or the directory where the last *.cqs calibration file was saved.

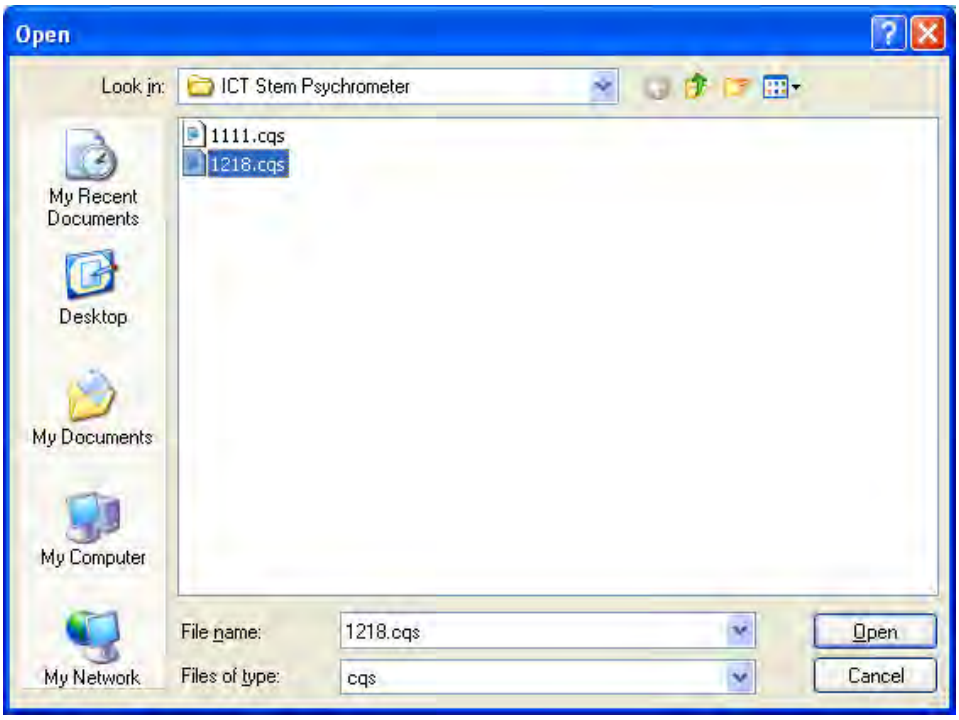


Figure 51 Loading a *.cqs calibration file from Hard Disk Drive

16.6.4 Calibration Live View Mode

It is recommended that a minimum 30 to preferably 60 minutes thermal equilibration time be left between the handling and loading of each calibration solution. These figures are arbitrary in nature and designed to err on the side of caution to ensure all thermal gradients introduced to the psychrometer through handling of the chamber, introduction of samples of different temperatures, be allowed to dissipate so as not to cause errors in the calibration.

This can cause a calibration to be a long and time consuming process. An alternative protocol is to utilise the Live View feature incorporated within the calibration function. This is a more intensive protocol based on active interpretation of empirical data to determine how long the psychrometer takes to return to thermal equilibrium after loading a calibration solution.

To activate the Calibration Live View click the Live View icon in the upper right hand corner of the calibration tab

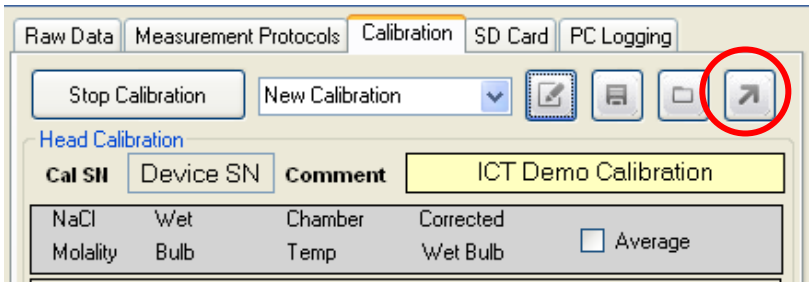


Figure 52 Calibration Live View icon

The Live View window initialises the microprocessor before continuously displaying the live values from all three thermocouples inside the psychrometer. Both dT and Wet Bulb will be elevated well above zero µV after loading the calibration solution. What must be determined is how long it takes for both values to reach and remain stable at zero µV. The user can apply discretion as to what constitutes a stable zero µV in relation to thermal equilibrium being reached. The values displayed below would constitute an adequate thermal equilibrium to initiate the next calibration data point measurement.

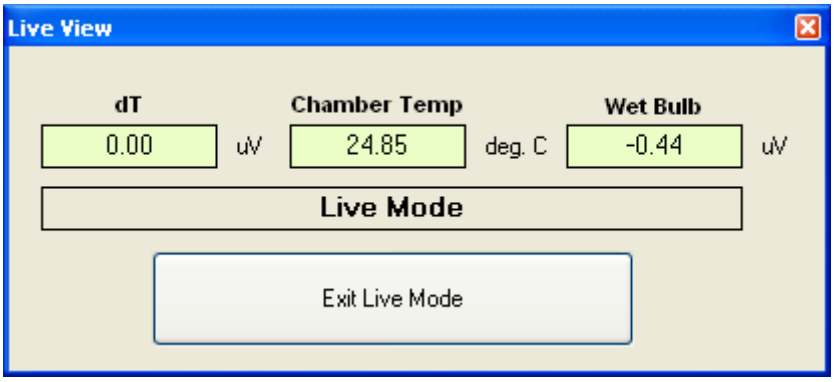


Figure 53 Live View Window – thermal equilibrium achieved

16.6.5 Calibration Summary file (*.rdf)

The calibration summary file is attributed the name of the psychrometer chamber that was calibrated. The file consists of the calibration intercept and slope that was generated after performing the minimum 3-point calibration using known NaCl solutions. It also contains the basic reference information related to the calibration such as the serial number of the PSY1 instrument that the calibration was conducted with; the calibration comment and the date and time the calibration was completed.

0.88

-3.87

PSY0AB03

ICT Demo Calibration

26/10/2012_14:48:36

16.6.6 Calibration File

The *.cqs calibration file is simply a text (*.txt) file that records and stores the raw calibration values for every calibration solution measured for a specific calibration run of a psychrometer. This file is stored on the Micro SD card or can be saved to the computer's hard drive to allow loading and editing it at a later date. This can be a useful feature if a calibration cannot be finished or the user wishes to save each data point for feare of the OS crashing and the calibration data lost.

The first line of the *.cqs file is the header line or comment entered by the user. Then data is stored in a simple table the left hand column is the Molal solution concentration from 0.1, 0.2, 0.3, 0.4, 0.5, and 1.0 Molal which is the standard calibration concentration range. The column continues for 1.2, 1.4, 1.6, 1.8 and 2.0 Molal concentrations for Extreme environment calibration range. The subsequent 3 columns of the table refer to the direct measurements recorded during calibration process, Wet Bulb, Chamber Temp and Corrected Wet Bulb.

Values are only entered if measured by the PSY1. Because the data file can be edited there made be instances where only 1 value appears in a column, most commonly this would be the far right column for corrected wet Bulb if the user has entered a nominal value for the purpose of demonstrating the calibration function or have values from a previous calibration that were manually entered into the calibration file.

Note 35 a minimum of 3 data points must be measured (or manually entered) to be able to generate a calibration slope and intercept. Any fewer data points cannot yield a suitably linear calibration.

16.6.7 Calibration History File

The calibration history file maintains a chronological record of all the calibrations performed on the psychrometer over the life of the instrument. Every time a calibration is made and saved using the four digit serial number of the psychrometer the raw data for each calibration solution are stored in the file including;

i. wet bulb depression,
ii. chamber temperature at which the measurement was made, and the
iii. corrected wet bulb depression
iv. Serial Number of the PSY1
v. Comment
vi. Date & Time

It provides a good reference to look at calibration drift over time.

HCDATE_26/10/2012_14:47:49
CC_Check Calibration Drift
CS_PSY0AB03
01_2.45_25.00_2.45
02_4.55_25.00_4.55
03_6.40_25.00_6.40
04_7.90_25.00_7.90
05_9.80_25.00_9.80
10_19.00_25.00_19.00
12_ _ _
14_ _ _
16_ _ _
18_ _ _
20_ _ _
HCDATE_26/10/2012_14:41:30
CC_ICT Demo Calibration
CS_PSY0AB03
01_2.60_25.00_2.60
02_4.50_25.10_4.49
03_6.20_24.90_6.22
04_7.90_24.80_7.94
05_9.60_24.80_9.65
10_18.80_24.90_18.85
12_ _ _
14_ _ _
16_ _ _
18_ _ _
20_ _ _

Note 36 if the thermocouple is broken and replaced the relevance of the chronological calibration data are lost. A new thermocouple will have no correlation with the calibration history of a previous thermocouple. It is effectively now a different instrument.

17 Installation

17.1 In-situ Measurements of Stem Water Potential

The stem psychrometer can be installed on woody, herbaceous and hollow (Bamboo) stems, greater than 10 mm diameter. With additional care, preparation and specific clamps the stem psychrometer can also be used on fruits and leaves.

When attaching the psychrometer it is important not to over tighten the clamping mechanism (except on woody stems) so as not to crush, or cause damage to softer plant tissues. Typically, finger pressure is sufficient to correctly tighten the clamp and ensure a vapour seal between the sample and the chamber well. Over tightening, can in the short term affect the measured stem water potential value, introducing an error and in the long term (and extreme cases) cause mechanical damage to the vascular tissue.

WARNING 12 - The Stem Psychrometer should not be used with species that exude latex or resin from within the xylem. If the latex is clearly compartmentalised and contained within the phloem which can be permanently removed and prevented from entering the chamber, it is possible to persist with the installation and use the stem psychrometer on these species.

(a) (b)

Photo 19 shows latex exudates in (a) which is unacceptable to install the stem psychrometer onto whereas (b) has been prepared in more detail and xylem exposed below the source of the latex and the stem psychrometer can be successfully installed.

17.2 Selecting a Sample

The minimum diameter of the sample stem is limited by the aperture of the chamber well of the stem psychrometer. The chamber well is oblong in shape, approx 6 mm long by 3 mm wide. It is recommended to select stems of greater than 10 mm diameter to ensure a good and reliable vapour tight seal on the stem. Cylindrical stems of smaller dimensions (about 5 to 7 mm) whilst theoretically possible pose a significant sealing problem and are rarely, if ever, successful. It is recommended to avoid such difficult installations.

Small stems with flattened portions are more conducive to efficient sealing. There is no limit on the maximum stem diameter for instrument attachment other than that imposed by the clamp size. In situations where it is not possible to easily, or safely access small diameter lateral branches, the psychrometer can be installed on large diameter trunks or leaves. This is covered in more detail in the sections, Installation on large diameter stems and installation on leaves.

NOTE 37 - stem water potential is an absolute measure of the water status of the plant tissue at the point of measurement. Whilst gradients will exist vertically in the plant, stem water potential measured on a lateral branch adjacent to the stem (which may be small enough to attach a psychrometer using one of the two standard clamp sizes) will be directly representative of the stem water potential of the adjacent main stem or trunk of the plant. This measurement will be a true reflection of the plant interaction with the ambient environment and the stem psychrometer provides a convenient and non-destructive method to continuously measure that variable.

A clamping device is required to attach the psychrometer to a plant stem. Two sizes of clamps are available that should meet 80% of all stem psychrometer installations:

a. Small Clamp (PSY-SC) for stem sizes up to 25 mm diameter and;
b. Large Clamp (PSY-LC) for stem sizes between 25 to 50 mm in diameter.

The purpose of the clamp is to securely hold the psychrometer in contact with the stem of the plant. Clamps are made of Lexan a polycarbonate resin thermoplastic that has great strength and thermal properties. Thus, the clamp will not induce a temperature gradient to the psychrometer and artificially influence the results.

Photo 20 Small Clamp attached to an herbaceous stem

Photo 21 Large Clamp attached to a woody stem

17.3 Sample Preparation

17.3.1 Sample Preparation on Woody Stems

Woody stems are preferred but most herbaceous species also lend themselves to this technique. On woody stems, expose a suitable area of water conducting xylem tissue or sap wood (approximately 3 cm x 1 cm) to ensure that the chamber well of the psychrometer will be completely covered by the sample. Remove the bark, phloem and cambium layers and use a single edged razor blade to scrape a flat area of xylem upon which to mount the psychrometer.

Note 38 Use relatively short, straight passes with the razor blade in a forwards and backwards motion. Be very careful to maintain a level plane rather than a scooping action that will cause a concave surface. It is not possible to achieve a vapour seal with a psychrometer on a concave (or convex) surface.

Photo 22 use a single sided razor blade to expose the xylem and scrape a flat surface

It is very important to achieve a flat surface when exposing the xylem. The calibration lid can be used as a surrogate for the psychrometer chamber to visually check the flatness of the prepared site. Ensure that no small gaps exist between the calibration lid and xylem surface by looking for flecks of light between the two surfaces. If no light can be seen then proceed to cleaning the prepared site.

Photo 23 use the calibration lid to check for a flat surface of the exposed xylem

Thoroughly clean the area with distilled water and wipe dry. This will remove spilled cell contents. It is important to the success of the installation that all living tissue is removed and no free water is left on the xylem surface. Often, some degree of xylem wounding is unavoidable. In species incorporating resinous tissue or significant proportions of living cells intermingled with xylem conduits (e.g. ray cells), great care should be taken in sample preparation to avoid contamination of the sample site. The importance and significance of fully removing all living tissue and cleaning the site thoroughly are demonstrated in Video 21 Installation Issues.

Photo 24 use a wash bottle of distilled water to wash away the spilt contents of cells

Photo 25 use a lint free tissue such as a Kim Wipe to dry the exposed xylem rub vigorously several times to ensure the stem is completely dry

17.3.2 Identifying the xylem

It is not always easy to determine the water conducting xylem or sap wood of a tree. Many underestimate the bark thickness of trees. For example there is a widespread misconception that the Lemon Gum (*Eucalyptus citriodora*) is thin-barked. This due to the presence of a band of green tissue resembling the deeper cambial layer of other species, when the tree's outermost bark is scarified or scratched. This phenomenon is common to numerous trees, including the London plane, Chinese elm and many tropical species.

This green tissue layer is actually composed of living cells which contain chlorophyll and enable the tree trunk to produce energy via photosynthesis. Indeed, rather than being an indication of "thin bark," it is an important factor in tree defence, providing energy for the vital process of compartmentalization, etc. ***Mauget Technical Bulletin # 01-10-15***

Therefore, it is very important to have a thorough knowledge of the vascular anatomy of the experimental plant before commencing installation of the psychrometer. It is recommended to use a sacrificial or non-measurement tree, and fully excavate the outer layers of the tree to confidently identify the depth, colour and location of sapwood.

(a) (b)

Photo 26 insufficient site preparation has been performed in (a) as the site preparation has failed to expose xylem. This is evidenced by the small symmetrical oblong shape that perfectly matches the stem psychrometer well. The psychrometer has been attached to living tissue that has grown into the chamber well creating a perfect callus cast of the chamber well on the surface of the stem.

In (b) sufficient bark and living plant tissue has been removed to expose the non-living but hydraulically conductive xylem or sap wood. Note the series of colour changes from the black outer edge of the bark through to the white sapwood/xylem. This exercise should have been performed on a non-measurement tree prior to first installing the psychrometer

Note 39 a common mistake in the installation of stem psychrometers is the failure to expose a sufficiently large area of xylem. Woody plants and trees particularly, utilise approx only 10% of their xylem for daily transpiration. The remaining 90% provides a capacitive buffer to mitigate the diurnal impact of cavitations caused by high levels of water stress. Therefore, what may seem like excessive damage of the stem has little if any medium to long term damage to the plant. It can be considered analogous to a pruning scar. Conversely, failure to remove any and all living tissue, cambium, phloem and osmotic fluids generated by damage to vessels during excavation, **WILL** cause major damage to the Psychrometer. Within hours of installation any living tissue that has not been removed and or washed away from the installation site will begin growing into the chamber and rip the fine thermocouples from the chamber requiring the instrument to be returned to ICT for repair.

Photo 27 is the result of failure to expose xylem or sap wood on a redwood branch during installation. Note the distinctive shape of the psychrometer well raised above the flat preparation surface. There are even the three perfectly shaped copper posts moulded in callus tissue.

Photo 28 is the result of failure to fully remove all living tissues from the xylem surface through thorough washing with distilled water and drying of the surface prior to installation. It only requires exposure to a small amount of cambium tissue to generate callus growth which will occur within hours of installation.

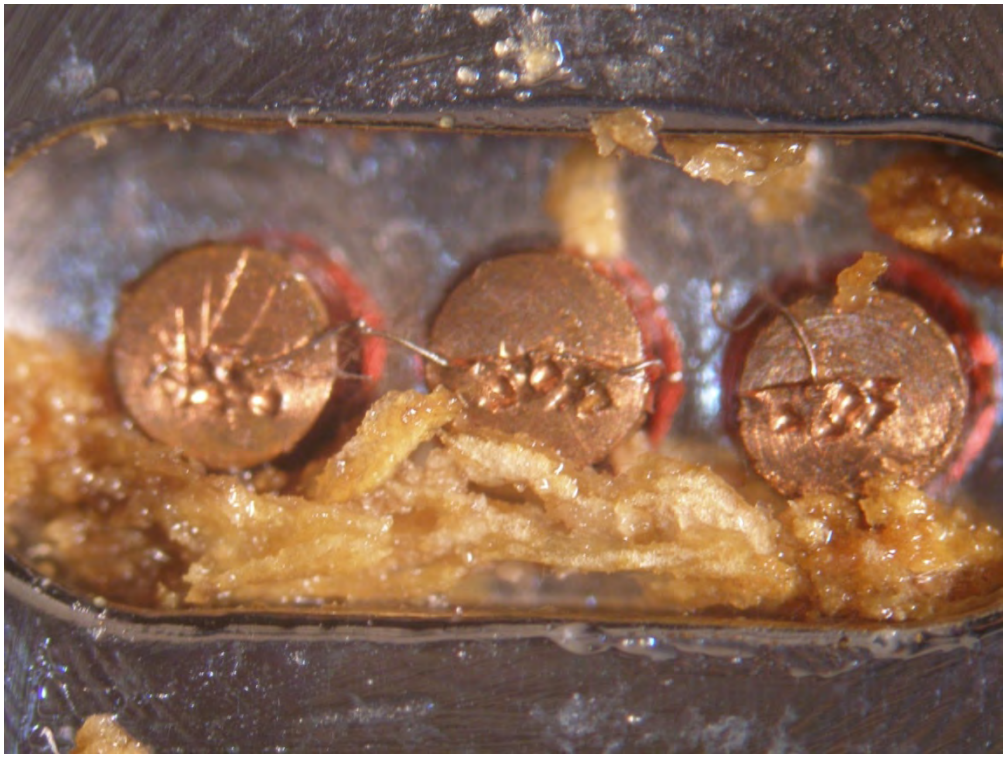


Photo 29 is the corresponding psychrometer chamber form the above installation. Note the callus residue in the chamber and the broken Thermocouple-S on the (right hand side)

17.3.3 Sample Preparation on Herbaceous Stems

On non-woody or herbaceous stems, site preparation is even more critical. Exposing the chamber to discrete xylem is often impossible and would involve considerable wounding. Wounded herbaceous tissue tends to respond with callus formation more quickly than woody stems and this severely limits the period of reliable measurements. Often, abrasion or scraping of the cuticle to expose the cell layers adjacent to xylem conduits, followed by thorough rinsing and wiping will result in reliable measurements for at least a week following attachment. This will vary considerably with species and preparation success. Correlating measurements with a pressure bomb may be required to establish a successful technique for some species.

Photo 30 use a razor blade to expose the water conducting tissues

VIDEO 22 – the complete process of preparing the stem and attachment of the psychrometer is demonstrated in the Installation Video. It is recommended that this video be watched prior to attempting an installation for the first time.

17.4 Positioning Thermocouple-S

Prepare the stem psychrometer for attachment by removing the calibration disk holder and fixing on the clamp. Be sure that Thermocouple-S, which is to be in contact with the sample, is extended to the face of the chamber well by gently pushing it from one side or the other rather than grabbing it with forceps and pulling it. Thermocouple-S only needs to be just at the surface and not extended beyond the face of the chamber. A **Video 23** demonstrating the Adjustment technique recommended to position Thermocouple-S should be watched prior to attempting this task for the first time.

WARNING 13 NEVER, grab or pull the thermocouple with forceps. Any tensile force applied to the thermocouple will break the tiny wires.

Thermocouple-S is much longer than Thermocouple-C which is easily identified when viewed under a 20X (or better) dissection microscope. In addition to the visual difference in length of the Thermocouple wires, Thermocouple-C is located adjacent to the psychrometer cable and Thermocouple-S is located distant to the psychrometer cable.

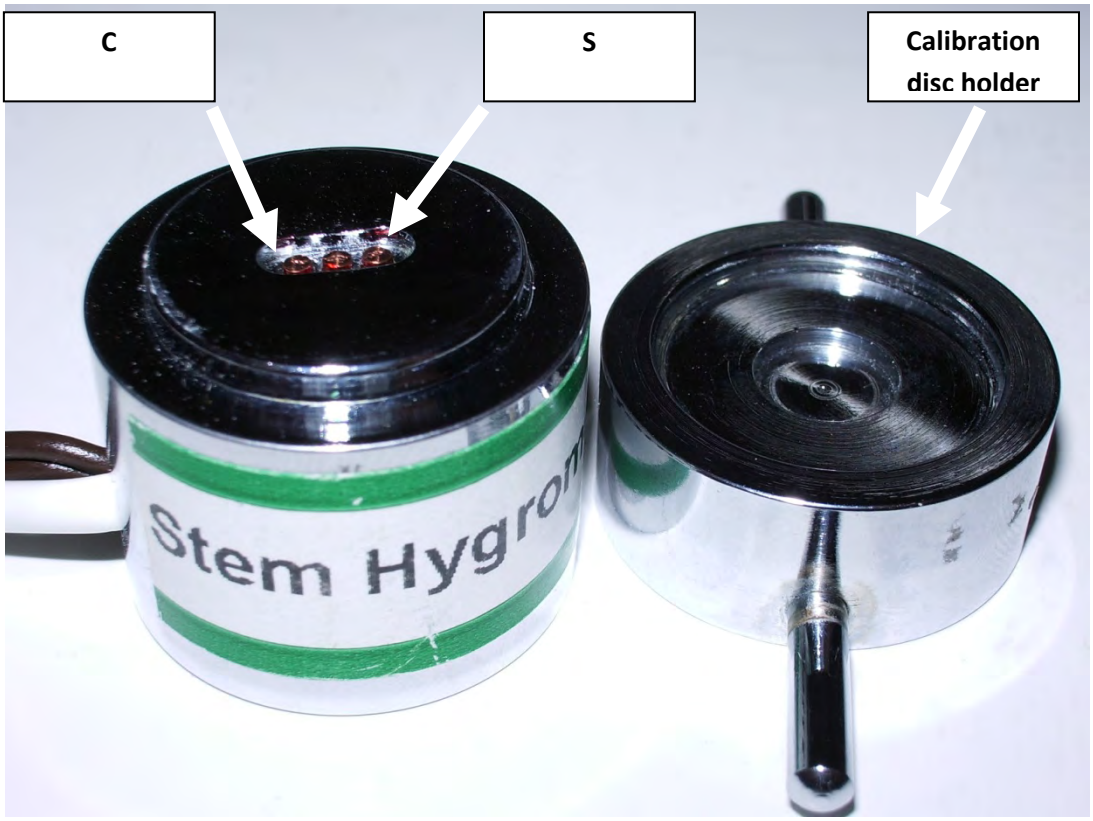


Photo 31 ***Location of Thermocouple-C & Thermocouple-S and Calibration disc holder***

17.5 Instrument Attachment

Orientate the psychrometer chamber so that the long axis of the oblong chamber well is running axially along the plant stem. When a suitable site is prepared the psychrometer can be attached using the clamp provided or some customized variation, depending upon the requirements. The instrument should be placed squarely onto the stem, avoiding any sliding across the stem surface and firmly attached. Typically, finger pressure is sufficient to correctly tighten the clamp and ensure a vapour seal between the sample and the chamber well. Excessive clamping pressure should be avoided as this may squeeze unwanted sap into the chamber and result in unreliable measurements. Clamping pressure should be checked periodically, especially on water stressed samples, since stem diameters vary significantly in some species as they dehydrate.

Photo 32 a psychrometer attached to a cotton plant stem. Silicone vacuum grease has been smeared across any exposed xylem. The installation is now functional but requires thermal insulation to reduce the influence of rapid changes to ambient thermal gradients.

17.6 Sealing the Exposed Site

Inert silicon grease, stable under high temperatures (e.g. Dow Corning vacuum grease) should be applied to any exposed sapwood that remains after the attachment of the psychrometer. This is necessary to reduce local evaporation and the possibility of inducing water potential gradients in the tissue. Also, apply some grease around the junction of the sample and stem psychrometer.

However, before doing this it is important to test the integrity of the vapour seal between the psychrometer and the stem. An imperfect vapour seal can be detected by directing an airstream at the junction of the chamber and the stem with the PSY1 in Live mode and watch the dT and Thermocouple-C values for erratic fluctuations. If both readings are stable during the application of a stream of air, a vapour seal has been achieved and the installation is good. If the values become erratic a vapour seal has not been achieved, therefore the installation is not good and you must reinstall.

As this step is performed before applying silicon grease it is possible to modify the existing installation site. If any grease has been applied before this step the whole installation site may need to be abandoned as the silicon grease will contaminate the site and affect or even prevent readings being made. It may be possible to scrape off excess grease and re-clean the site for re-installation of the instrument, but it is not recommended.

NOTE: Large quantities of vacuum grease are not necessary and strongly advised against. The vapour seal is, and must be, made between the flat face of the Psychrometer chamber and the xylem. Vacuum grease is intended as a buffer and for sealing any exposed xylem as a result of site preparation. Silicon grease cannot be used to vapour seal the chamber. Eventually, any gaps that are vapour sealed by the grease will fail allowing grease to ingress to the chamber and cause the installation to fail. Remove as much grease as possible before uninstalling the instrument from the stem to avoid contamination of the chamber well.

17.7 Insulation

At this point, the attached instrument and portion of stem should be insulated with styrofoam or cotton wool or a suitable facsimile. The foam insulation is not intended to prevent the diurnal temperature change. Instead, it is intended to act as a thermal buffer zone to depress the rate of temperature change during the period of measurement to determine the Psychrometric Wet Bulb Depression. Finally, wrap the foam covered chamber and stem with Aluminium foil to reflect direct radiation and prevent it from heating the whole installation.

Alternatively, an insulated temperature control jacket can be fitted around the installation and connected to a bath circulating temperature controlled fluid. This is usually only possible in a laboratory situation but is particularly efficient at limiting temperature gradients and maintaining constant instrument temperature, two highly desirable factors in the reliable use of the instrument.

Photo 33 attaching a high density foam insulation jacket around the psychrometer chamber and the plant stem to provide a thermal buffer form rapid changes in ambient temperature

17.8 De-Installation & Re-Installation

During installation avoid using excessive silicon grease when sealing exposed xylem and the junction between the chamber and the stem. Conservative use of silicon grease at installation will minimise the risk of contaminating the inner chamber with grease during de-installation. This is sometimes a hazard when removing an instrument and the danger can be reduced by wiping away excess grease before removing the psychrometer and by lifting the psychrometer straight off the site of attachment rather than allowing it to slide.

A Video 24 dedicated to the de-installation of the psychrometer should be watched prior to installing or de-installing the psychrometer for the first time.

It is also recommended that a second **Video 25**, demonstrating the preparation of the psychrometer for re-installation in the field, be watched before attempting installation for the first time. This video demonstrates the added issues associated with field work and important tips for successful installation of the stem psychrometer in the field.

WARNING 14 if the psychrometers have been permanently uninstalled at the end of the season or a research project do not pack them up without first cleaning them. Please refer to the sections on Cleaning and Storing the psychrometers.

17.9 Installation on Large Diameter Stems

As previously described the preferred installation technique is to attach the psychrometer to a small lateral branch of the plant or tree adjacent to the main stem or trunk. In most case this is easily achieved. However, in large diameter mature trees lateral branches may be very large in diameter themselves exceeding the 50 mm capacity of the large clamp (PSY-LC) or the lowest branches of the canopy may be many metres or tens of metres above the ground and not be easily or safely accessible. In these instances the psychrometer must be attached directly to the main stem or trunk.

It is possible to achieve a successful installation on a large diameter stem using one of two methods; the first is a conventional method of exposing the xylem or sap wood with a single edged razor blade or second is to employ a specialised drill known as a Forstner bit that is used in woodworking and cabinet making. Both methods require customisation of the clamping mechanism to secure the psychrometer to the stem and both have issues that must be considered to achieve a successful result.

17.9.1 Modified Surface Attachment

The same procedure is used for a large diameter stem as is used for a small diameter stem. The xylem must be exposed by removing the bark, phloem and cambium and a flat surface on the xylem or sapwood prepared with a single edged razor blade large enough to attach the psychrometer and achieve a vapour seal. The difficulty of achieving this is increased on large diameter stems as they are typically vertical in orientation, changing the working angle for scraping the flat surface and have much thicker bark. The thickness of the bark requires that a much larger area must be excavated in order to scrape a flat surface for attachment of the psychrometer. So large in fact, that the potential for localised evaporation of the stem around the installation is greatly increased even when using silicon grease to cover the exposed site.

Photo 34 large areas of bark, phloem and cambium must be excavated to expose a sufficiently large flat surface to install a psychrometer on the surface of a large diameter stem

Once the site has been prepared the psychrometer must be carefully and securely attached to the stem. Orientate the cable so that it points to the ground to avoid preferentially channelling water from stem flow down into the installation. And carefully place the chamber directly onto the prepared surface.

Now a modified clamping mechanism must be employed. As each installation and stem diameter is different ICT does not supply a standard clamping system for large diameter trees to support surface mounted attachment. Many novel clamping systems have been developed by our customers.

The simplest method is to use a tie down strap and buckle (which can be purchased from a hardware store of various lengths to suit the diameter of the stem). The tie down strap is then wrapped around the psychrometer and pulled tight against the stem. This is much more difficult than it sounds and requires the assistance of two people. The psychrometer is sitting on a flat surface without any bracing, so the action of tensioning the tie down strap will force the psychrometer to slide laterally across the prepared xylem surface. This has the potential to damage the sample thermocouple (Thermocouple-S) which is raised up to touch the stem of the plant, and/or repositioning the chamber on remnants of living tissue that will grow into the chamber. Or at very least dislodge it from the perfectly flat surface compromising the vapour seal.

A very successful (but elaborate) clamping system developed by Dr. George Koch Northern Arizona University in conjunction with his collaborators from Humboldt State University in California, lead by Prof. Steve Sillett, involved a sprung platform with custom curved mounts to fit the shape of the stem (or large diameter branch) that it is strapped to. The whole mechanism is then secured to the stem under tension using tie down straps and buckles. This technique is advantageous in that the vertically sprung mounts provide a reference for positioning the psychrometer on the stem that limits the potential for the psychrometer to slide across the xylem surface when tightening the psychrometer in place.

Photo 35 custom designed clamping system for large stems, installation on large lateral branch of *sequoia sempervirens* Coast Redwood shown.

17.9.2 Forstner Bit Installation

A Forstner bit is used in preference to a conventional drill bit, auger bit, spade or speed bore bit because it bores a precise, perfectly flat surface at the bottom of the hole. The perfectly flat surface enables a vapour seal between the chamber and the xylem.

A Forstner bit consists of two cylindrical cutting surfaces around the perimeter of the drill. A centering point is used to start the hole before the two cutting edges shear the wood fibres at the edge of the bore. This provides good balance and ensures a perfectly bored hole square to the surface. The radial cutting edges in the centre of the drill plane off the material at the bottom of the hole with precision, this produces the perfectly flat surface required for achieving the vapour seal with the psychrometer.

The outside diameter of the stem psychrometer chamber is 25 mm or 1”. The most common Forstner bit size is 25 mm. However, this is too tight making insertion of the chamber into the drilled hole difficult. The bark must be manually excavated with a knife to enlarge the hole to achieve insertion but it is not possible to confidently verify a vapour seal with the xylem is achieved.

For this reason a less common 26 mm Forstner bit must be used to drill a hole large enough to accept the chamber. A 26 mm Forstner drill bit leaves a 0.5 mm gap around the perimeter of the psychrometer chamber allowing for ease of insertion without obstruction or modification of the hole. The chamber is held firmly in place by the bark of the tree, simplifying the attachment and clamping requirements, and the bark provides an added layer of insulation immediately around the body of the psychrometer.

(a) (b)

Photo 36 (a) shows a close up of the Forstner bit cutting surfaces that create the perfectly flat xylem surface for installation of the psychrometer and (b) shows the Forstner bit being used in a cordless drill to bore the hole for installation of the psychrometer

Note 40 Forstner bits are typically used by master craftsmen to make high value furniture and cabinetry work. They are not designed for boring green wood fibres. They require great force to push them into the material, so are normally used in drill presses or lathes rather than in portable drills. Unlike most other types of drill bits, they are not practical to use as hand tools. Therefore, it is important to practice using the drill bit before using it to install a psychrometer if you are to achieve optimum results. Forstner bits have no mechanism such as the flutes of a conventional drill bit, to clear wood fibres from the hole. As with any drilling of plant stems it is imperative that the hole is drilled in short passes, regularly removing the drill bit to clean the wood fibres to prevent friction and excessive heat buildup.

(a) (b)

Photo 37 (a) shows a perfectly flat bottom hole bored into the xylem of a large diameter tree using a 26mm Forstner bit (b) inserting the psychrometer chamber into the bored hole.

WARNING 15 – some species can exude Kino vein sap as a wound response. DO NOT use this installation site. The Kino will immediately flood the psychrometer chamber and gum up the Thermocouples and prevent measurements from being made. If the psychrometer becomes fouled by Kino vein sap it can be cleaned, but will require several thorough cleanings. It is highly recommended to clean the chamber whilst the Kino vein sap is still moist as it is easier to remove than when dry.

Photo 38 a Forstner bit hole that has bored through a region of Kino vein within the xylem of the stem. Note the blackened venation in the bottom right quarter of the hole which is where the exudates were released from.

Note 41 Kino is a reddish-brown gummy substance formed by Eucalyptus species in response to injury. Specifically, it is an aqueous solution of polyphenolic compounds formed in veins or pockets in the wood or bark. Kino veins also have been referred to as "gum veins." Kino is commonly seen as an exudate on the bark (branches and trunks) of many eucalypts. The formation of Kino vein occurs in response to injury from; insects, fungi, and fire. It is thought to be a defence mechanism, particularly in regard to pathogen infections. A type of "barrier zone" has been reported to form in the xylem after kino vein formation (Tippett and Shigo, 1981). Drought stress is reported to reduce the production of kino. Ethrel has been used to stimulate kino formation (Tippett, 1986). Although all Eucalyptus species produce kino (i.e., for the 93 species which have been evaluated), species vary in vein location and sensitivity to venation. Most species form kino veins in xylem,

17.9.2.1 Cleaning a Forstner Bit Hole

The hole bored into the xylem of the stem must still be rinsed with distilled water (several times) to ensure the living tissues of the spilt cells caused by the boring process are washed clean of the prepared site.

Again, lint free tissues such as Kim Wipes must be used to vigorously dry the xylem surface at the bottom of the bored hole as well as the water introduced into the hole that will have been absorbed by the surrounding bark, especially at the bottom arc of the hole where the water runs to after washing. Failure to sufficiently dry this water will result in an extended delay to reach vapour pressure equilibrium between the psychrometer and the sap wood or in the worst case, compromise the installation through condensation that would prevent any measurements being made.

17.9.2.2 Forstner Bit Hole Attachment

As mentioned a 26 mm diameter Forstner bit leaves a 0.5 mm gap around the perimeter of the psychrometer chamber. This tolerance allows easy insertion of the chamber into the hole, which in many species can be up to 25 mm deep or, the full depth of the psychrometer chamber itself. It also affords the ability to easily remove the chamber to verify vapour sealing with the xylem. This is done by putting a series of small dots of silicon grease on the outer face of psychrometer chamber. Then carefully insert the psychrometer and twist the chamber in the hole to smear the grease, much as you would when using the calibration lid Video 26. You can then remove the chamber from the hole and verify that a seal has been achieved.

Once satisfied, reapply a small amount of grease to renew the vapour seal, orientate the cable of the psychrometer so that it points to the ground (to avoid preferentially channelling water from stem flow down into the installation) and reinsert the psychrometer. Then simply fasten the psychrometer to the tree using a tie down strap and buckle pulled tight against the stem. Unlike fastening the psychrometer to a modified surface attachment on a large diameter stem, the psychrometer does not slide across the stem surface when tensioned as it is held firmly in position by the bark. Then mount the PSY1 to the tree using the mounting bracket supplied.

Photo 39 PSY1 and psychrometer chamber installed in a Forstner bit hole on a large diameter stem

17.9.2.3 Sealing a Forstner Bit Installation

Silicon grease can be used in one of two ways to ensure a long term vapour seal on a Forstner bit installation. First is as described in the preceding section, silicon grease can be applied directly on the face of the chamber. Alternatively, to limit the potential for silicon grease to compromise the xylem surface or thermocouples a bead of silicon vacuum grease can be run around the perimeter of the psychrometer chamber at the interface between the stem and the psychrometer sealing the 0.5 mm void. Again this is not designed to provide the vapour seal. This has already been achieved with the interface of the psychrometer face and the flat bottom hole bored into the xylem of the stem. It is designed to act as a barrier to foreign bodies entering between the hole and the chamber and to insure that the vapour seal is not momentarily lost through the swaying action of the tree.

17.9.2.4 Insulating a Forstner Bit Installation

The insulation around the chamber from being surrounded by bark is useful but not sufficient to fully dampen and insulate the psychrometer form ambient thermal gradient. The whole installation and stem should still be wrapped in foam and covered with Aluminium foil to reflect direct radiation and prevent it from heating the whole installation.

Photo 40 foam and aluminium foil insulating a Forstner bit installation on a large diameter stem

18 Instrument Setup & Configuration

18.1 Instrument Information

The instrument information panel is a summary of the instruments setup and status. It provides a simple, intuitive Graphical User Interface (GUI) that displays the configuration settings as stored in the instruments memory (non-volatile RAM). Important operational information such as Serial Number, Firmware versions, internal battery voltage, external power supply and charging status are, immediately obvious. You can immediately download data and or change the descriptive information such as Name, Comment and Psychrometer Serial Number directly on screen.

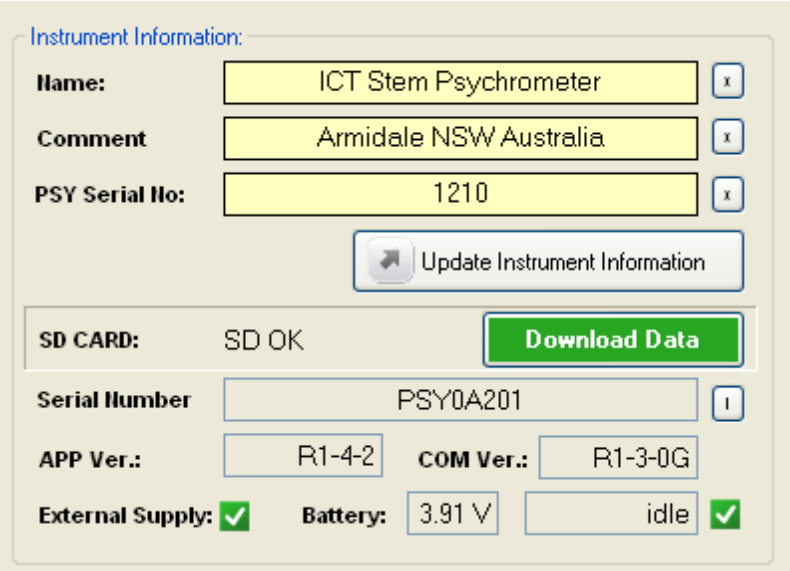


Figure 54 Instrument Information Panel

The function, purpose and the intended use for each of these parameters is described in detail below:

18.1.1 Name:

This field provides the user with a site Identifier to relate the data set back to the plant being measured. The name is stored in the header line of the data file.

18.1.2 Comment:

a 28 character field for the user to store a comment with the data set. The comment is stored in the header line of the data file.

18.1.3 PSY Serial No:

Enter the individual serial number of the stem psychrometer chamber here. Each Psychrometer is labelled with a unique 4-digit number. This enables the user to generate a specific custom calibration for each chamber. The calibration information is stored on the internal Micro SD card under the 4 digit serial number of the chamber located within the "psycal" folder.

18.1.4 The X:

Entries in these fields can de deleted by clicking on the x

18.1.5 Update Instrument Information:

Clicking this icon saves your changes to non-volatile RAM so your settings remain in memory and active even after disconnecting from the PSY1.

Note 42 whenever any of these 3 fields are updated a new header line is inserted into the data file. This provides a tracking mechanism by which columns of processed data, (that can be logged such as water potential) can be referenced to the data and calibration slope & intercept used to automatically calculate the data.

18.1.6 SD Card:

The status of the SD card is displayed. If a SD card is inserted and functioning correctly it will display SD OK.

Figure 55 SD Card Status & Download Icon

If the SD card is removed or not inserted the message NO CARD is displayed.

Note 43 it is possible to think you have pushed the card in, but failed to have it click in fully. Be sure to listen for the clicking sound when inserting otherwise the PSY1 will rightly state NO CARD.

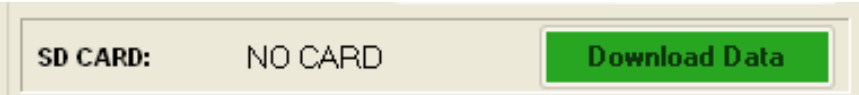


Figure 56 SD Card Status & Download Icon

Note 44 Clicking on the *"Download Data"* icon will take you directly to the SD Card Tab. This tab is detailed fully in the SD Card section.

18.1.7 SD Card Initialisation:

Upon insertion of the MicroSD card the PSY1 Initialises the card then performs a simultaneous communication and format check. If the SD card fails the communication and

initialisation check the SD card status is reported as **SD ERROR**. This means the SD card is damaged and should be replaced with a new MicroSD card.

Note 45 ICT International recommends SanDisk MicroSD Card's however, any brand of MicroSD card is compatible and should perform well in the PSY1 within the limits of the card's own specifications.

18.1.8 SD Card Formatting:

If the SD card uses a higher level of formatting such as exFAT then a message will appear saying "WRONG FORMAT" at which point you would reformat the SD card to FAT32 format.

18.1.9 Instructions to reformat a MicroSD Card

(1) Remove the card from the PSY1
(2) Place it in the USB card reader
(3) Insert it in to a computer.
(4) Right click on the drive and choose Format.
(5) Select FAT32,
(6) Name the "Volume Label" PSY1
(7) Check the "Quick Format" box
(8) Click Start

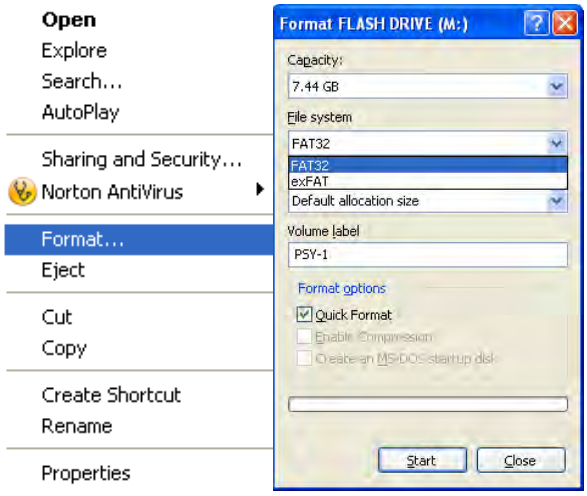


Figure 57 Microsoft Windows Right Click Menu for Formatting a Drive

Note 46 The PSY1 works fine with FAT and FAT32 file formats. It is not designed to be compatible with exFAT (extended File Allocation Table format also known as FAT64). This is a new format that has yet to be adopted by commercially available SD cards for precisely the reason that it would be incompatible with most electronic instruments, mobile phones and cameras.

18.1.10 Format Check:

If the format check is ok, a check of the serial number is performed to see if a valid CSV file can be created. If this check is ok, the SD Card status to reported as SD OK

18.1.11 File Name Error:

If the instrument serial number has been lost or corrupted the check will fail, and the SD Card status is reported as **FILENAME ERROR**. At this point, please contact your local ICT distributor in your country or ICT International direct for support.

Note 47 the SD card is “hot Swappable” meaning it can be ejected and inserted while connected. The SD card status is updated in real time.

18.1.12 Serial Number:

The Overall instrument serial number is displayed. This serial number is used automatically as the 8 character data file name. When using the instrument for the first time or inserting a new SD card upon making the first measurement the data file is automatically created using this number as the file name with .csv extension. Once downloaded to a PC the file name can be changed but data can only be saved to the SD card in this format. This serial number is also stored in the header line of the data file. It is used for technical support purposes by ICT technicians.

Figure 58 Serial Number Field

18.1.13 I icon:

clicking on the I icon toggles between the overall instrument serial number and the serial numbers of the individual circuit boards that make up the instrument.

Figure 59 Individual Serial Number Toggle Icon

18.1.14 APP Serial #:

The serial number of the Application circuit board that is custom designed and manufactured specifically to measure the Stem Psychrometer. This serial number is also stored in the header line of the data file. It is used for technical support purposes by ICT technicians.

Figure 60 Application Board Serial Number Field

18.1.15 COM Serial #:

The serial number of the communication circuit board that operates the Micro SD card, USB and wireless radio communications of the instrument. This serial number is also stored in the header line of the data file. It is used for technical support purposes by ICT technicians.

Figure 61 Generic Communication Board Serial Number Field

18.1.16 O:

Clicking on this icon toggles between the individual circuit board serial numbers and the overall serial number field.

Figure 62 Overall Instrument Serial Number Toggle Icon

18.1.17 APP Ver.:

The firmware version number loaded into the application circuit board. The user should review this at regular intervals and compare it against the current version available from the ICT web site www.ictinternational.com/download.html if a new version is available the user can upgrade the firmware using ICT's Boot Strap Loader Utility software. This firmware version number is also stored in the header line of the data file. It is used for technical support purposes by ICT technicians.

Figure 63 Application Board Firmware Number Field

18.1.18 COM Ver.:

The firmware version number loaded into the communication circuit board. The user should review this at regular intervals and compare it against the current version available from the web site www.ictinternational.com/download.html if a new version is available the user can upgrade the firmware using ICT's Boot Strap Loader Utility software. This firmware version number is also stored in the header line of the data file. It is used for technical support purposes by ICT technicians.

Figure 64 Generic Communications Board Firmware Number Field

18.1.19 External Supply:

These fields display the status of any external power supply that may be directly connected to the instrument such as:

(a) An external 12V DC power supply either, mains powered or solar powered
(b) The external voltage supply whether from Solar Panel or battery
(c) The Internal Battery voltage
(d) The internal battery status either idle (not charging) or Charging

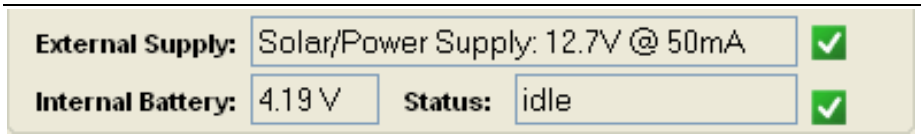


Figure 65External Power Supply Status Fields

These fields are dynamically updated showing a Green check box when external supply is present or a red box with a white X when there is no external supply present. The external power supply voltage and charging current can be stored to the Micro SD card as a measured parameter, with each water potential valued logged. This is detailed in the section on SD Logging Options

Figure 66 External Power Supply Status Icons

18.1.20 Battery:

The instruments internal 4.3V Lithium polymer, rechargeable battery voltage is displayed in real time. This battery voltage can be stored to the Micro SD card as a measured parameter with each water potential valued logged. This is detailed fully in the section on SD Logging Options

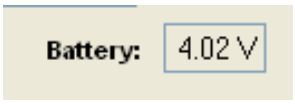


Figure 67 Internal Battery Voltage Field

18.1.21 Status:

This field indicates the status of the instrument. If the instrument is fully operational and charged the field displays the message ***"Idle".*** Alternatively, if the instrument's internal battery has dropped below the operational threshold of 3.7V and an external power is attached, the instrument displays the message **"charging".**

Figure 68 Internal Battery Voltage Status Fields

18.2 Raw Data Tab

The "**Raw Data**" tab displays in real time, data being measured by the instrument. Each output is clearly displayed and labelled. A "**Measurement Status**" indicator keeps the user informed of the progress of each measurement (when connected to the software).

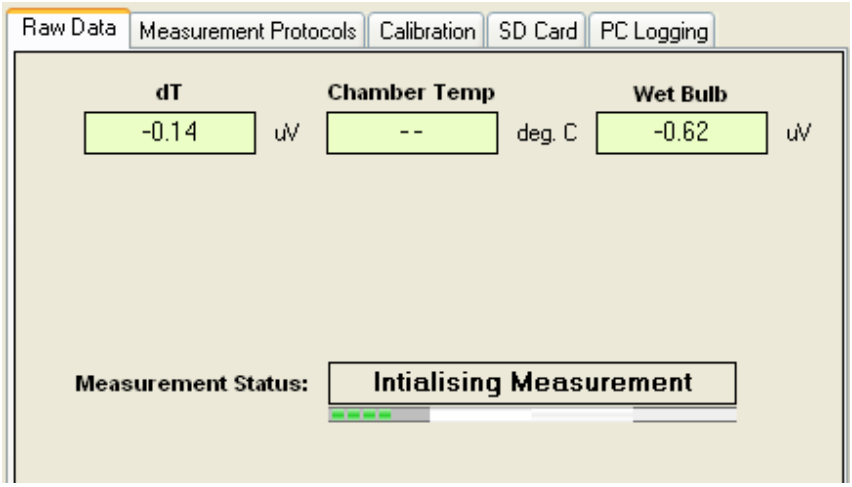


Figure 69 Raw Data Tab displays measured values from the Thermocouples of the Psychrometer

No values are displayed either before a measurement is made or after a measurement is completed. This is done to avoid confusion over where the values on screen have come from. After a measurement has been completed the results can be reviewed in the dialogue box located in the bottom left hand corner of the GUI window

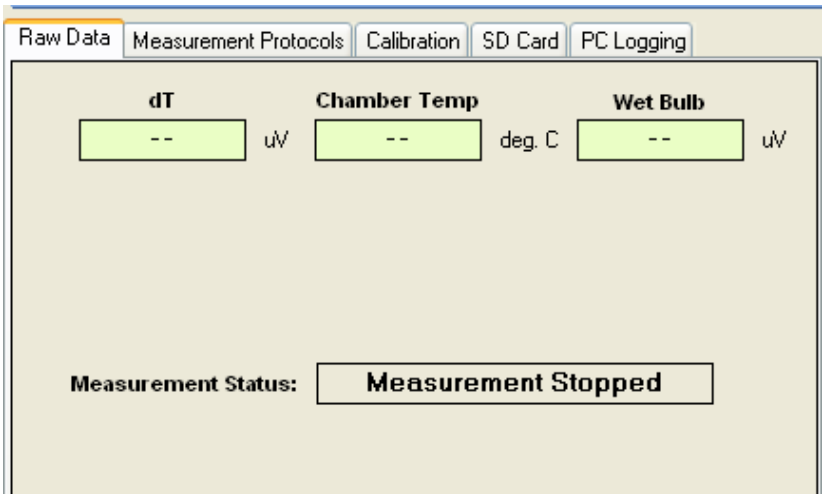


Figure 70 No values are displayed in the Raw Data Tab Fields unless a measurement is in progress

Note 48 When the instrument is in "Live" Mode values are constantly displayed in real time, refreshed at the sampling rate of the instrument, 10 Mhz or every 0.1 second.

Each measurement parameter displayed on the Raw Data tab is explained in detail below:

18.2.1 dT:

Displays the difference in temperature (dT) measured in (µV) between the Thermocouple-S and Thermocouple-C. In the manual mode dT will be measured initially at the commencement of the measurement process and this value remains on display until the completion of the measurement.

Note 49 In the "Live" mode the dT is continuously monitored and updated.

18.2.2 Chamber Temp:

Is the measured temperature (°C) of the entire psychrometer chamber body. The measurement is made by a Copper-Constantan thermocouple located within the insulated base of the psychrometer chamber. It is representative of the ambient conditions under which the measurement is made. The chamber temperature measurement is made and subsequently displayed after the Peltier cooling pulse and psychrometric wet bulb measurement has been made.

Note 50 In the Live mode the Chamber Temp is continuously monitored and updated.

18.2.3 Wet Bulb:

Is a direct measurement (µV) of Thermocouple-C within the chamber of the psychrometer. Thermocouple-C is initially the Dry Bulb and then, following condensation of water vapour via Peltier cooling, the Wet Bulb thermocouple of a classical Psychrometric measurement of vapour pressure.

Upon initiating a measurement Thermocouple-C is momentarily measured. This is a measure of the electronic noise or offset from electronic zero of the instrument which we call the Electronic Dry Bulb Offset (EDBO). The PSY1 uses this value as the zero set for the measurement and is automatically performed before each measurement either in the manual mode or when configured for automatic logging.

Note 51 In the Live mode the Chamber Temp is continuously monitored and updated.

18.2.4 Measurement Status:

This is a user feedback feature that details each stage of the measurement process:

18.2.4.1 Initialising ADC

Powering up and stabilising the microprocessor

18.2.4.2 Initialising Measurement

Equilibrating the electronic circuit

18.2.4.3 Peltier Cooling

Generating and passing a Peltier cooling pulse through Thermocouple-C to cool the thermocouple and condense water within the chamber from the gaseous phase to liquid phase, resulting in a Psychrometric Wet Bulb Depression

18.2.4.4 Measurement in Progress

Waiting for a user definable time (typically 6 seconds) before reading the µV output of Thermocouple-C, this is the Wet Bulb Depression. The measurement then continues to monitor the thermal decay as Thermocouple-C returns to zero. This is done as a verification of performance and accuracy of the measurement.

Note 52 if Thermocouple-C is dirty microscopic beads of water will remain attached to the thermocouple preventing it from quickly returning to its original starting temperature. In extreme cases the Peltier curve will be indiscernible and simply drift indefinitely never returning to the starting temperature. It should also be mentioned that a similar response may occur in samples with very wet (close to zero) water potentials. To be rule out a dirty thermocouple always perform a verification test of the chamber before installation (see Appendix A PSY Test Procedure)

18.2.4.5 Measurement Stopped

No measurement is currently being performed.

18.2.5 Show Diagnostics

The diagnostic parameters are not typically used in the course of a routine measurement. This facility is designed to be used in conjunction with an ICT technician to assist in troubleshooting possible problems with the instrument such as a broken thermocouple. For this reason the diagnostics parameters are hidden from view. They can be turned on and turned off by accessing the "***PSY***" menu and selecting "**Show Diagnostics**" or alternatively, "**Hide Diagnostics**".

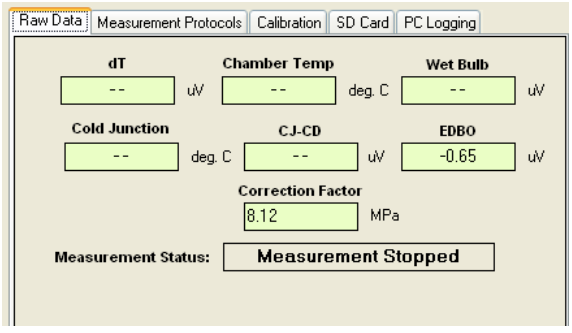


Figure 71 Raw Data Tab with Diagnostics Displayed

18.2.5.1 Cold Junction

Is a calibrated measure (°C) of the differential Thermocouple reference located inside the PSY1, potted in a thermal insulating compound on the circuit board. This measurement is made using a Military grade specification thermistor in an insulated environment for ultra high accuracy.

18.2.5.2 CJ-DJ

Is a measure in (µV) of the stability of the analogue inputs

18.2.5.3 EDBO

Electronic Dry Bulb Offset. This is a measure (µV) of the electronic noise or offset from electronic zero of the instrument prior to making a measurement of Thermocouple-C. The PSY1 uses this value as the zero set for the measurement and is automatically performed before each measurement either in the manual mode or when automatically logging.

18.2.5.4 Correction Factor

Is the relationship between vapour pressure and temperature in MPa / °C . It is applied to the value of dT (in degrees) to adjust the apparent water potential measurement for the effect of any temperature gradient between the sample (Thermocouple-S) and the measuring junction (Thermocouple-C). It is displayed in the dialogue box with the raw data for each measurement logged to the data file.

18.3 Measurement Statistics

The statistics facility is designed to provide the user with a real time comparative check of the performance of a psychrometer. From a series of readings the PSY1 will automatically monitor and display the Maximum, Minimum and Average Water Potentials measured. It will then calculate and display the difference between these measured values. This facility provides a convenient evaluation tool of the psychrometer chamber during setup to ensure optimal performance prior to deployment. It is also a good diagnostics tool for trouble shooting a faulty psychrometer chamber and, can even be used as a positive feedback tool during lab based manual measurements.

It is not designed to replace statistical analysis of data which should be performed on logged data, downloaded from the instrument. These statistics are not controlled and will be applied to any values recorded by the PSY. This means the statistics calculated could be from multiple psychrometer chambers attached to or interchanged with the PSY1 through the course of testing therefore rendering the results invalid. To reset the statistics click the "**r"** icon to the right of the "**Difference**" field.

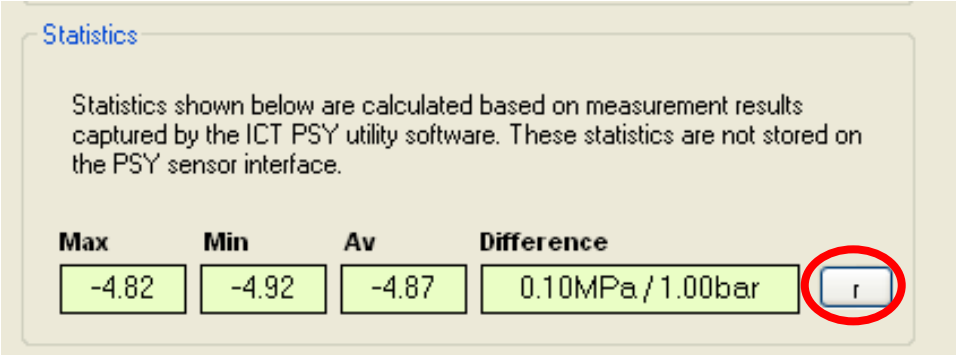


Figure 72 Statistics on manually performed measurements

19 Measurement Control

19.1 Measurement Mode

The drop down box provides a menu of the possible temporal logging intervals with which to operate the instrument.

19.1.1 Manual:

This mode allows the user complete control over the initiation of a measurement. A measurement can only be initiated by clicking on the Start Measurement icon. It is typically used to perform:

(1) An instrument verification check prior to field deployment
(2) A calibration of a stem Psychrometer chamber
(3) Destructive sampling of leaf tissue for leaf water potentials
(4) Destructive sampling of leaf tissue or sap for osmotic potentials
(5) Soil water potential measurements of excavated soil samples.

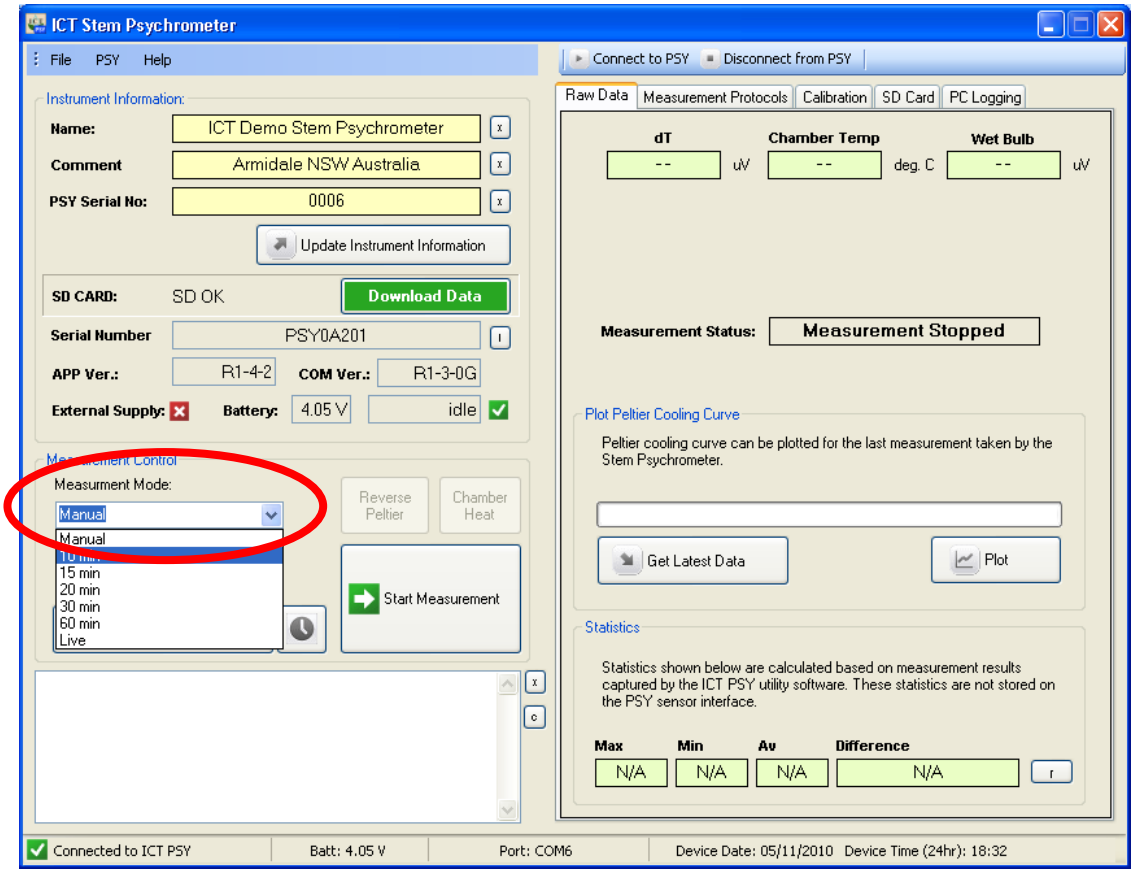


Figure 73 Measurement Control Mode set to "Manual"

Note 53 All readings initiated in the manual mode are saved to the micro SD card and saved direct to the PC (if PC Logging is activated). It is also possible to manually apply reverse Peltier currents to warm the thermocouple or invoke a chamber heating protocol by pressing the respective icons. These protocols are described in detail in the Reverse Peltier (warming) and Chamber Heating sections.

19.1.2 10 Min:

This is the minimum temporal resolution logging interval allowed in an automated data collection mode. Data collected more frequently than this has a high probability of disrupting the thermodynamics of the chamber by preventing the return to thermal equilibrium between readings and increasing microscopic beads of water on the thermocouples that will artificially appear to increase the readings (make the measurements less negative) therefore, introducing serious errors. This can be empirically demonstrated in the "***Manual***" mode by making successive measurements without any time interval between each measurement.

Note 54 It is recommended not to use 10 min temporal resolution logging interval unless you have done a precursor study of the plant, at the specific site under the prevailing environmental conditions to verify that 10 minute temporal resolution is indeed sufficient time to allow re-equilibration between measurements.

19.1.3 15 Min:

Optional temporal resolution logging interval often chosen for environmental research

19.1.4 20 Min:

Optional temporal resolution logging interval

19.1.5 30 Min:

This is a Good temporal resolution as it affords the plant sufficient time to re-equilibrate thoroughly yet still frequent enough to see rapid changes in plant water potential.

19.1.6 60 Min:

Optional temporal resolution logging interval

19.2 Live Mode:

Live mode is used as a diagnostic tool to ensure integrity of chamber thermocouples through stability of Thermocouple-C and dT values. Live mode in conjunction with Chamber Heating Protocol or Peltier Warming Protocol can also be used to test and verify a selected protocol before field deployment (See Appendix A for a PSY1 Test Procedure)

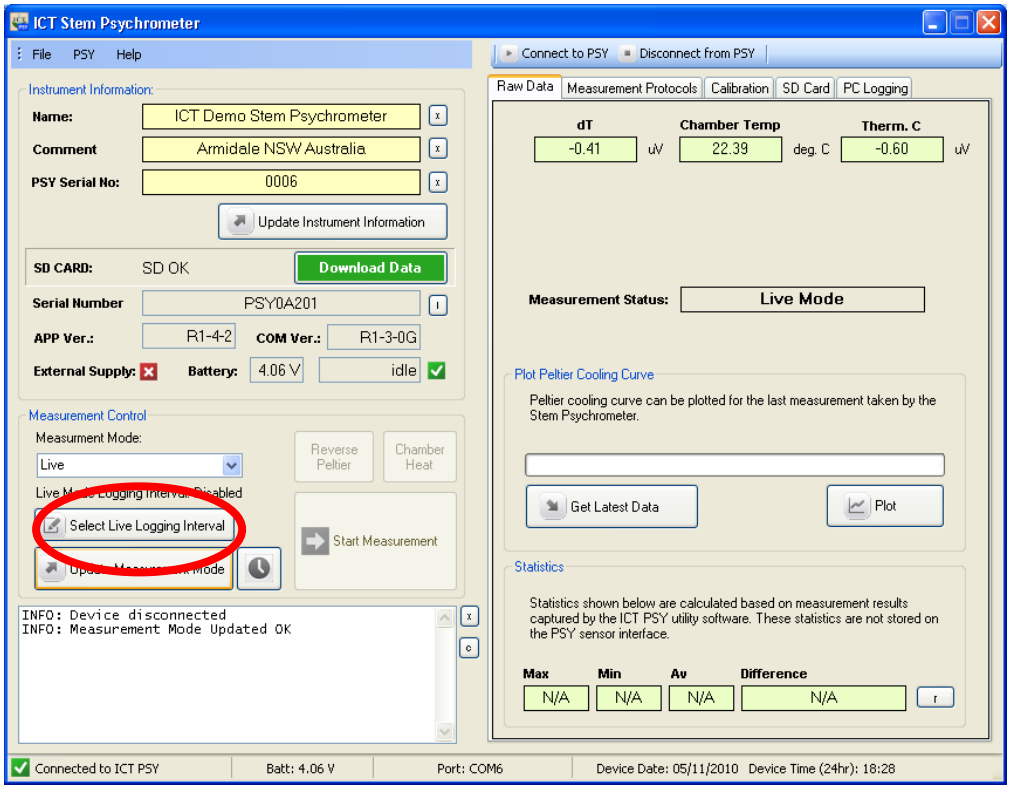
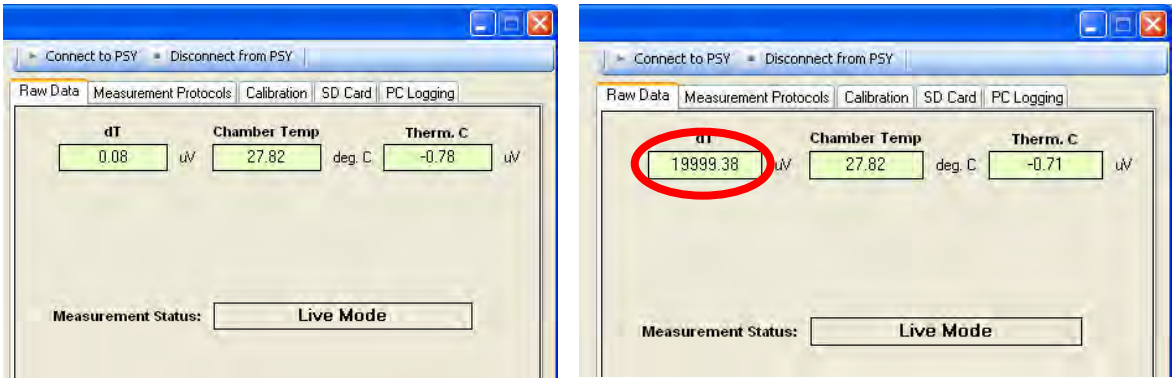


Figure 74 PSY1 Software set to Live Mode displaying real time values measured from the Thermocouples in the psychrometer



(a) (b)

Figure 75 (a) shows an expected output from Thermocouple-C when the Thermocouple is intact and in working order. (b) Shows the open circuit response of a broken Thermocouple-S. This chamber requires repair by ICT International.

Note 55 Please contact ICT International on the Service Desk via our web site www.ictinternational.com and submit a ticket for a Return Merchandise Authorisation Number (RMA #) and immediately return the chamber for repair together with a completed RMA Form and corresponding Service Desk ticket number. Instruments returned without an RMA form WILL NOT BE RPAIRED. Where the repair is urgent it may be possible to organise the dispatch of an exchange chamber to minimise the down time.

19.2.1 Live Logging Interval

The live data can be saved to a custom file extension*.lve on the Micro SD card. This can be a file name of your choosing and saved to your preferred folder location on the computer. Data can be logged at intervals between 1-60 seconds. Once the required logging interval is chosen, use the up and down scroll arrows or type the value directly into the field, and click on the "***Done"*** icon to commence logging.

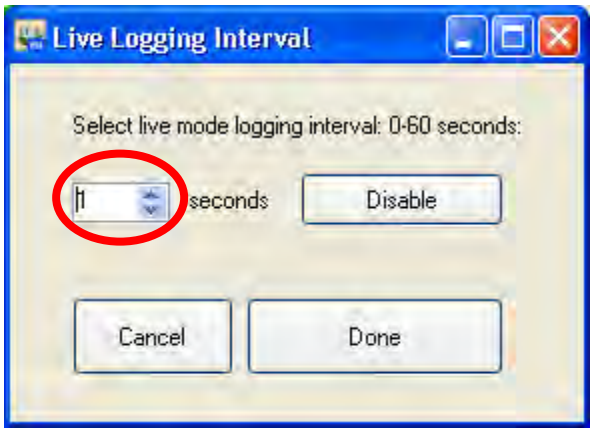


Figure 76 Live Logging Interval Window for and setting Live Logging mode intervals or deactivating Live Logging Mode

To stop logging in live mode, click on the "**Select Live Logging Interval**" icon to bring up the "Live Logging Interval" window.

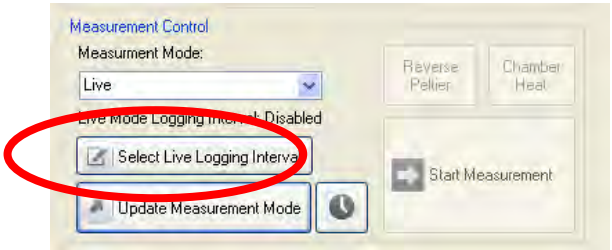


Figure 77 Measurement Control – Select Live Logging Interval

Then, click the "***Disable***" icon to reset to zero seconds and click "**Done**". Alternatively, use the scroll arrows to adjust the seconds to zero. Logging is now stopped but the instrument remains in live mode and the live display is still active.

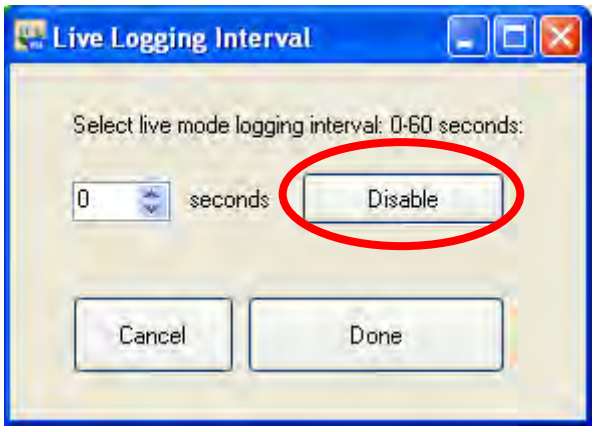


Figure 78 Live Logging Interval Window to deactivate Live Logging Mode

Note 56 the instrument uses more power when set to "Live" mode. It is recommended that when using "Live Mode" for extended periods you should connect an external power source to charge the internal battery.

Warning 16 - Never disconnect the instrument while in "Live" mode. As the instrument will continue to use power and drain the internal battery unnecessarily. It may also cause the internal battery to become completely discharged. When external power is connected and the battery is recharged above the hibernation mode the "Live" mode will automatically begin to drain power making it impossible to fully recharge the internal battery.

19.2.2 Live Data file

Below is an example of a Live Data, data file. The *.lve file extension is used for differentiation purposes only. The Actual file format is a Comma Separated Values (*.CSV) file that will automatically open in Excel or Sap Flow Tool (SFT1) Analysis software. The data file follows the same format as a psychrometer data file. It includes a Header line that records all of the instruments settings, Columns headings row, separate Date and Time Columns and the measured outputs from the psychrometer chamber.

Serial Number:	PSY0A201								
APP Serial #:	3000008								
Head Serial #:	6								
APP Ver:	R1-4-2								
COM Ver:	R1-3-0G								
Instrument Name:	ICT Demo Stem Psychrometer								
Comment:	Armidale NSW Australia								
Date	Time	Chamber Temperature (°C)	dT (µV)	Thermocouple C (µV)	Cold Junction (°C)	CJ-CD (µV)	Correction Factor	Internal Battery Voltage (V)	External Power Supply Present
5/11/2010	19:05:40	22.37	-0.17	-0.56	23.92	22.37	8.29	4.03	not present
5/11/2010	19:05:41	22.37	-0.17	-0.58	23.92	22.37	8.29	4.03	not present
5/11/2010	19:05:42	22.36	-0.16	-0.58	23.92	22.36	8.29	4.03	not present
5/11/2010	19:05:43	22.37	-0.13	-0.56	23.92	22.37	8.29	4.03	not present
5/11/2010	19:05:45	22.37	-0.14	-0.59	23.92	22.37	8.29	4.03	not present
5/11/2010	19:05:46	22.37	-0.16	-0.63	23.92	22.37	8.29	4.03	not present
5/11/2010	19:05:46	22.36	-0.16	-0.64	23.92	22.36	8.29	4.03	not present
5/11/2010	19:05:47	22.36	-0.15	-0.65	23.92	22.36	8.29	4.03	not present
5/11/2010	19:05:48	22.36	-0.15	-0.65	23.92	22.36	8.29	4.03	not present
5/11/2010	19:05:49	22.36	-0.11	-0.61	23.92	22.36	8.29	4.03	not present
5/11/2010	19:05:50	22.37	-0.11	-0.61	23.92	22.37	8.29	4.03	not present

Table 1 Example of a Live Data, Data File

19.3 Delayed Start

The delayed start function allows the user to configure the instrument in advance of use. In many situations it may be preferable to set all instruments to the same predetermined start time prior to deployment in the field. This can be done via the GUI software in the office prior to deployment in the field. Once in the field and the instruments have been installed and power is either manually turned on using the power switch (see turn on the instrument) or by connecting external power (see connecting a power supply to the instrument) which causes the instrument to automatically turn on and commence logging at the predetermined time and logging interval.

To operate effectively this function requires that the instrument's internal clock has been either synchronised with your computer or manually set to the correct local time of the region in which you are deploying the instruments. Failure to do so will result in erroneous data that will require manual post processing to correct the date & time stamp of the collected data.

Note 57 the instruments can only be set to start logging 23:59 minutes prior to starting as it works on a 24 hour clock only without a date variable. Therefore, a longer lead time is possible if after configuring the instrument you turn the power off.

To activate the Delayed Start function click on the Clock icon to the right of the Update Measurement Mode icon in the Measurement Control field.

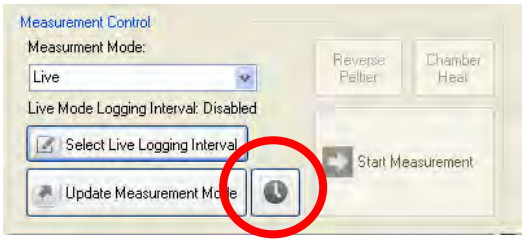


Figure 79 Delayed Start Icon

The Measurement Scheduler Window will appear. Begin by deselecting the "**Disable Delayed Start**" check box to enable the delayed start function.

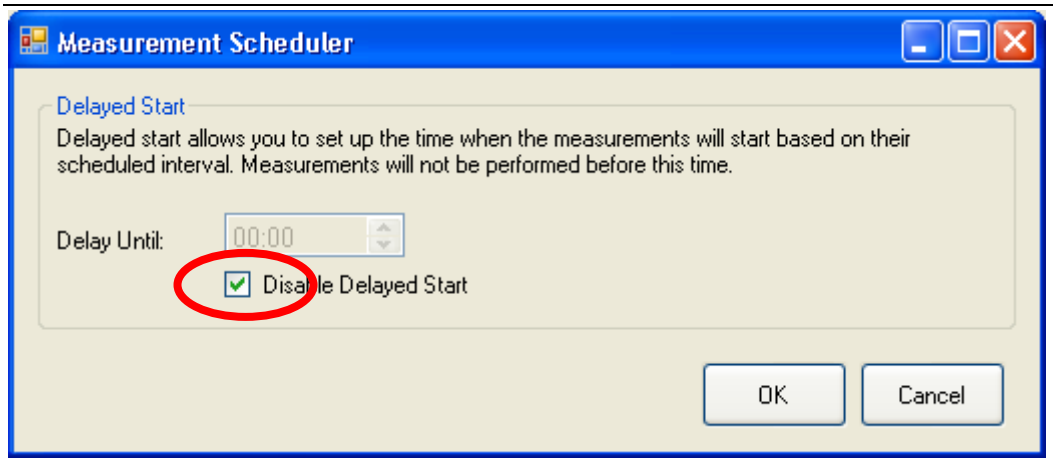


Figure 80 Measurement Scheduler Window – Enable Delayed Start

Next adjust the time that you require the instrument to commence measurements. This can be done by typing the precise time in hours and minutes in the respective time entry fields or utilising the scroll arrows to increase or decrease the time. To use the scroll arrows click in the hour entry field and click the scroll arrows up or down. Once, the required hour is set, click in the minute's entry field and again use the scroll arrows to adjust the minutes up or down as required. Once both the hours and minutes are set click ok.

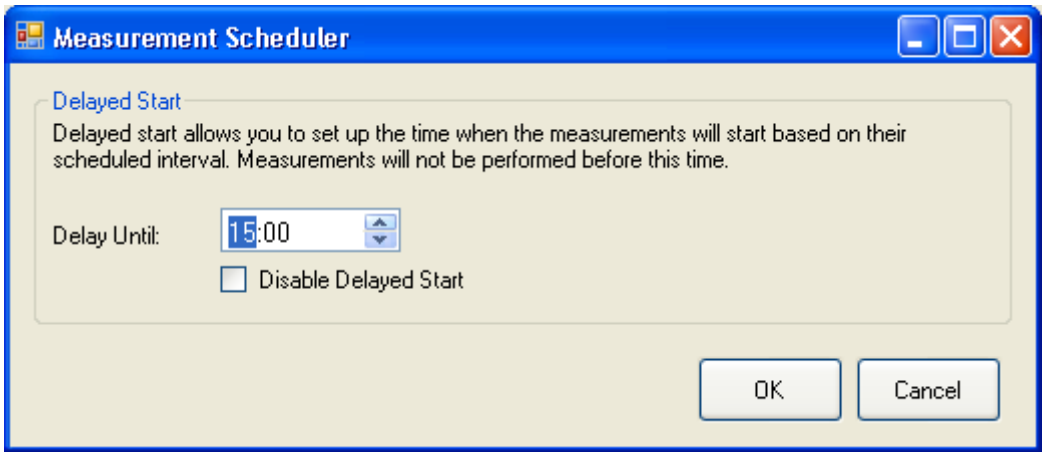


Figure 81 Measurement Scheduler Window – Set start time

When complete the Measurement Scheduler window will close returning you to the main GUI window. In the Dialogue Box a message confirming the change will be displayed INFO: Measurement Mode Updated OK.

19.4 Dialogue Box

The dialogue box is located in the bottom left hand corner of the PSY1 GUI software.

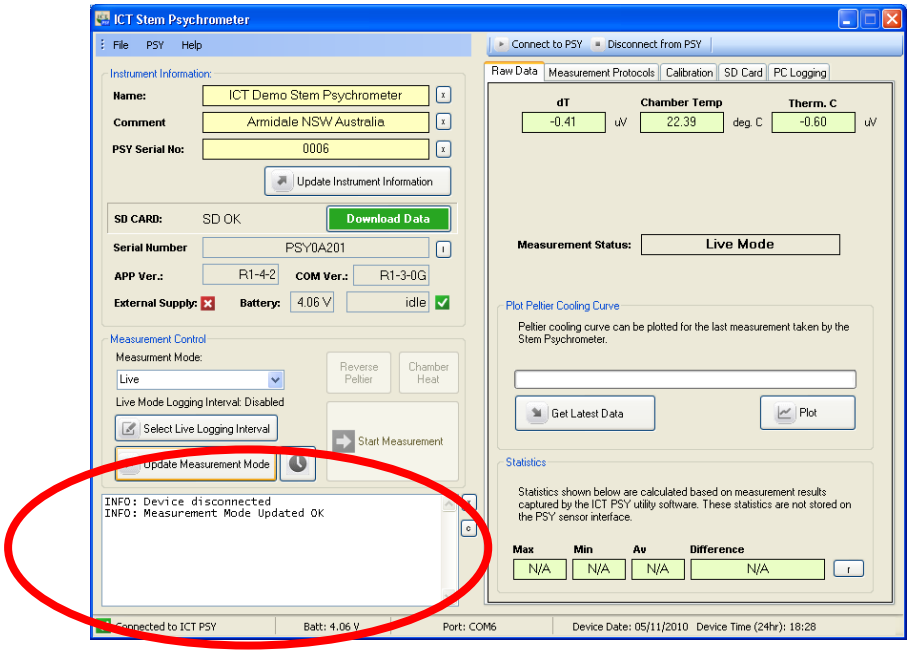


Figure 82 Dialogue Box location and Function

It is a field for dynamic user feedback from the instrument in response to actions performed by the user. When an action is performed by the user a response is immediately displayed either confirming the action is ok or warning that the action has failed and why.

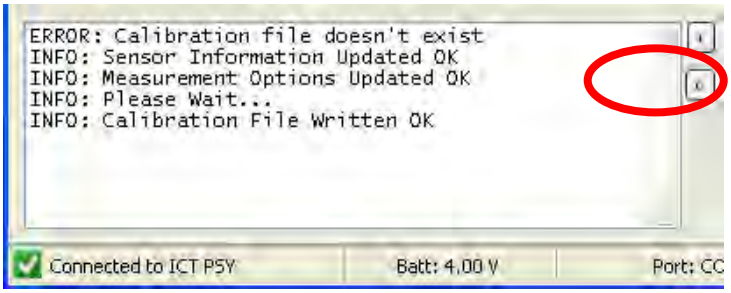


Figure 83 Dialogue Box – Example of user feedback messages & Copy Text function icon

19.4.1 C:

Clicking on this icon copies all of the information contained within the dialogue box and can be pasted into a word processing application such as Microsoft Word or Notepad. This can be a useful tool in diagnosing possible problems as exact feedback from the instrument can be emailed to ICT engineers for troubleshooting.

ERROR: Calibration file doesn't exist

INFO: Sensor Information Updated OK

INFO: Measurement Options Updated OK

INFO: Please Wait...

INFO: Calibration File Written OK

19.4.2 X:

Clicking on this icon clears the field of any previous information

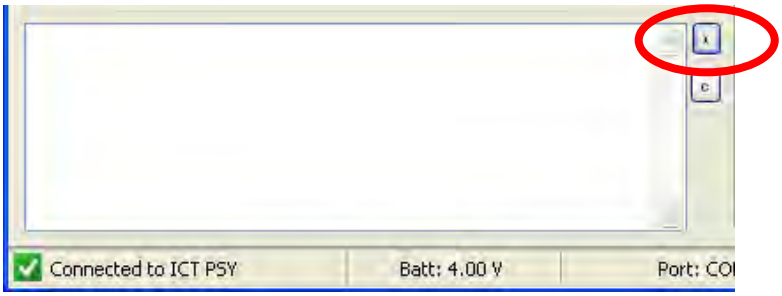


Figure 84 Dialogue Box Clear icon

19.5 Status Bar:

The status bar is located along the bottom of the PSY1 GUI and provides basic information about the operational status of the instrument.

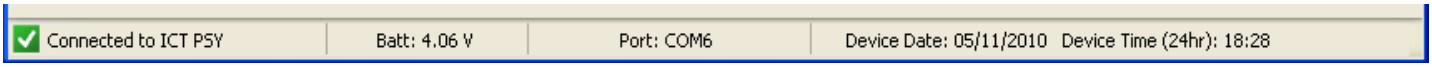


Figure 85 PSY1 Software Status bar

19.5.1 Connection status:

- Disconnected
- Connecting
- Connected to ICT PSY

19.5.2 Batt:

Displays the internal battery voltage of the instrument both prior to connection and once connected. Prior to connection it provides a very useful diagnostic tool should the PSY1 fail to connect due to a low internal battery voltage.

19.5.3 Port:

Displays the active COM port being used by the instrument associated with the open Software window, multiple instruments can be connected to a PC simultaneously on different COM ports by opening multiple software windows.

19.5.4 Device Date:

The current date of the instrument is displayed. This can be set manually by the user or synchronized with the PC Date & Time. (See section "***PSY Menu***")

19.5.5 Device Time:

The current time of the instrument is displayed. This can be set manually by the user or synchronized with the PC Date & Time. (See section "***PSY Menu***")

19.5.6 Help Menu:

19.5.6.1 About

The About Splash Screen displays the Software's:

- Product name
- Product Version
- Release date
- The ICT Web site link www.ictinternational.com

Figure 86 PSY1 "About" Splash Screen

19.5.7 Check for Updates

The updates fucntion can be automated however, a manual updates search option is availble via the Help menu. This will force the software to check the ICT web site http://www.ictinternational.com/downloads.html and search for any new software or firmware udates that may be available.

19.5.8 Support

The support option is split into two key functions (1) Create Support Log and (2) Start Debug File. These functions are designed to automatically collect configuration information for use by ICT engineers in troubleshooting problems.

19.5.8.1 Create Support Log

The support log automatically generates a file summarising the configuration settings of the PSY1 that can either be directly emailed to ICT or sent as a text file attachment. An example of a Support Log is shown in Appendix C – Support Log

19.5.8.2 Start Debug File

The Debug file interrogates the computer you are using documenting the Operating System, CPU capacity, RAM, connected Hardware, USB Com ports and drivers. It then records the communication sequence between the computer and ICT Devices connected to any USB Com port. This file is created when you "Start" a debug file and finishes when you "Stop" the Debug File or close the software. The file is saved as a .txt file that can be emailed to ICT engineers for analysis and trouble shooting.

Figure 87 Help Menu – Support Options - Create Support Log & Start Debug File

20 Peltier Cooling Curve

During each measurement Thermocouple-C is measured at a 10 Hz frequency for 30 seconds resulting in 300 readings per Peltier cooling pulse. A two second running average filter is applied to the output to account for any electrical noise. This data is then stored in RAM of the PSY1. In the manual mode this data can be recalled after each reading and immediately graphed.

The 300 raw data points for each Peltier cooling pulse can also be logged to a separate data file *_rdf.csv. This is configured through "**SD Card Logging Options**" via the "**PSY**" menu.

20.1.1 Get Latest Data:

This icon reads the raw data points from internal RAM and makes them available for plotting on screen in the PSY1 software. The Peltier cooling curve for the last measurement taken can be recalled and plotted.

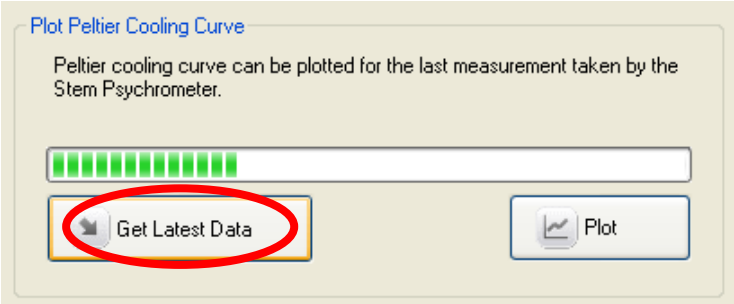


Figure 88 Peltier Cooling Curve - Get Latest Data icon

20.1.2 Plot:

Click this icon to automatically plot the Peltier cooling data.

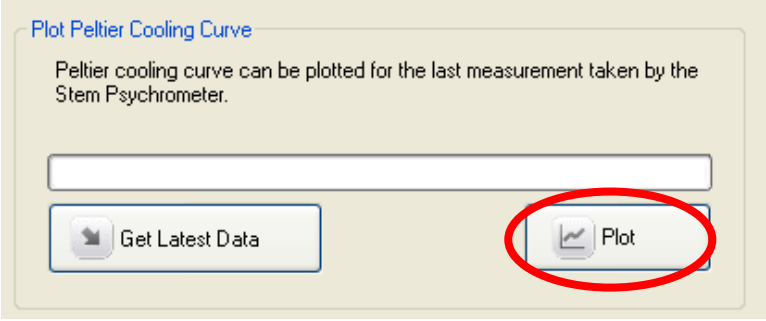


Figure 89 automatically plot the latest Peltier Cooling Curve data by clicking the Plot icon

20.2 Peltier Cooling Curve Plot

The graph generated displays time in seconds (s) along the X-axis and Thermocouple-C output (µV) on the Y-axis.

Time zero = the end of the Peltier cooling pulse. The plot begins at Time = 4.5 s after the end of the Peltier cooling pulse. This provides a 1.5 second section of plot prior to recording the Psychrometric Wet Bulb Depression at 6 seconds, the standard "wait time" protocol after the end of Peltier cooling. The plot of the Wet Bulb Depression plateau commences at 4.5 seconds after the end of cooling. The duration of the plateau will depend on two main factors;

(1) water status of the sample - a wetter sample (less negative water potential closer to zero MPa) will take longer to evaporate and,

(2) the cooling time – a longer cooling time (say 10 seconds) will condense more water on the thermocouple than will a short cooling time (say 5 seconds).

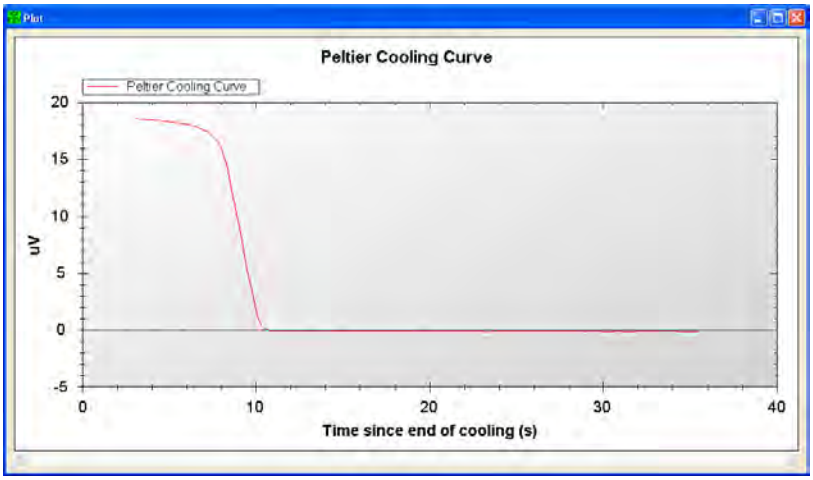


Figure 90 Shows the characteristic response of a clean Thermocouple-C; The output response of Thermocouple-C is in the range of 19 µV (for a1.0 Molal solution); the plateau of the psychrometric Wet Bulb Depression lasts until approx 10 seconds after the end of cooling and, rapidly falls to zero (the pre-pulse zero reference) and remains steady at this temperature indicating there is no thermal or electronic drift.

20.3 Peltier Cooling Curve – Diagnostic Tool

The decay of the Wet Bulb Depression as the output returns to zero reference (i.e., the thermocouple warms back up to the initial starting temperature after having been cooled) is indicative of the "cleanliness" of the thermocouple. Dirt and dust; silicon grease used to seal the chamber and; contact with living plant tissues that can accumulate through general field use, and oxidation of the thermocouples, both through general field use and or poor maintenance during storage, all cause the thermocouple response to be less sensitive, and take longer to (and be less likely to), return to zero after a cooling pulse.

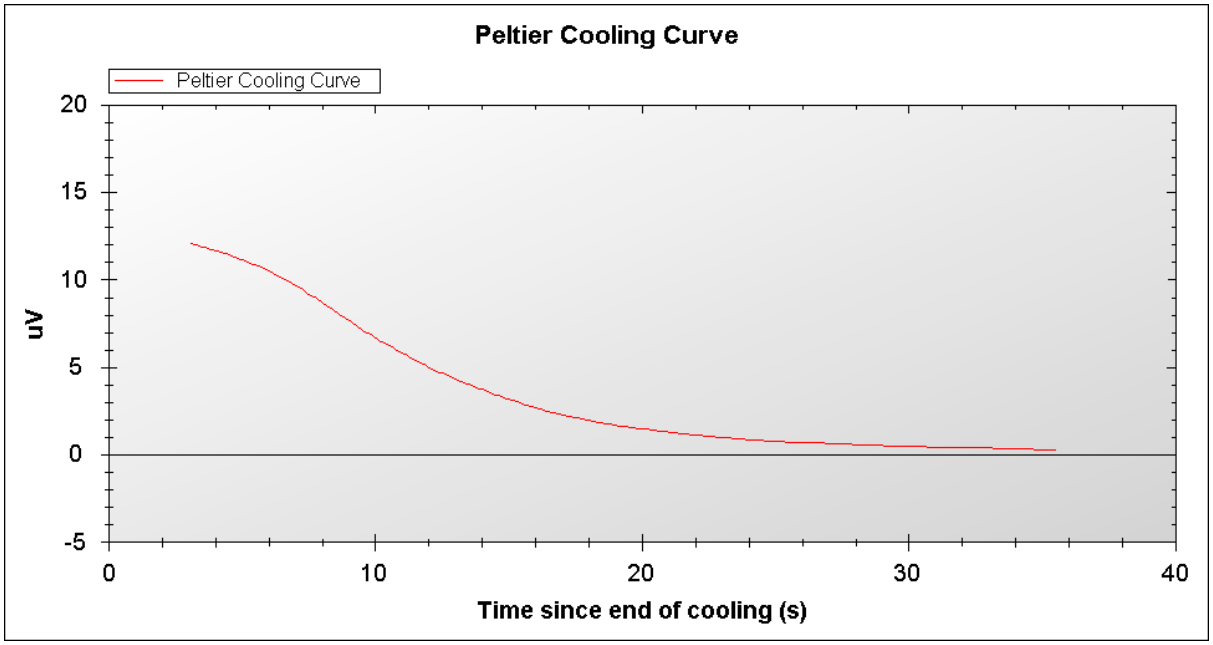


Figure 91 shows the characteristic response of Thermocouple-C that requires cleaning. Note the low output response of the Wet Bulb Depression (in the range of only 12 µV for a 1.0 Molal solution), the absence of a clear plateau representing the psychrometric Wet Bulb Depression and a long drawn out gentle gradient and failure to return to the pre-pulse zero reference.

A recommended performance and verification check of the pscyhrometers sensitivity and performance prior to deployment is as follows: place a 1.0 Molal calibration solution in the calibration lid and perform a measurement using a five (5) second cooling time and a 6 second wait time. For a clean, sensitive and well performing psychrometer the Wet Bulb Depression should generate an output of approx 19 µV, have a pronounced plateau between 4.5 seconds and 10 seconds with a rapid drop to zero (µV) at around 10 to 11 seconds returning completely to, and remaining stable at zero (µV). If this is not the case the thermocouples of the psychrometer should be cleaned see Cleaning the Psychrometer.

NOTE 58 For a particularly dirty psychrometer this procedure of cleaning and verifying may be required to be repeated up to 3 times. If a satisfactory response cannot be achieved within three attempts please contact ICT International for support.

20.3.1 Plot Options:

The graph generated by the plot function can be formatted using standard Windows formatting commands. These options are available by right clicking on the graph

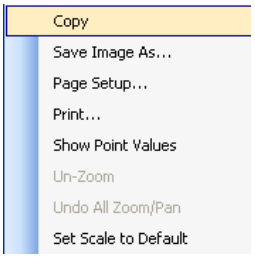


Figure 92 Windows Plot options

20.3.2 Copy:

The graph can now be pasted into a word processing document such as Microsoft Word for inclusion in reports.

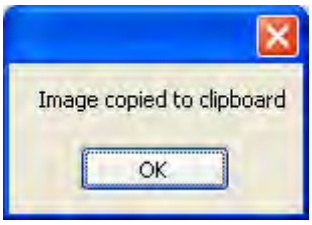


Figure 93 Image copied window

20.3.3 Save Image As...

The graph can be saved as an independent image in a range of image formats (most typically JPG) for inclusion in reports or other media.

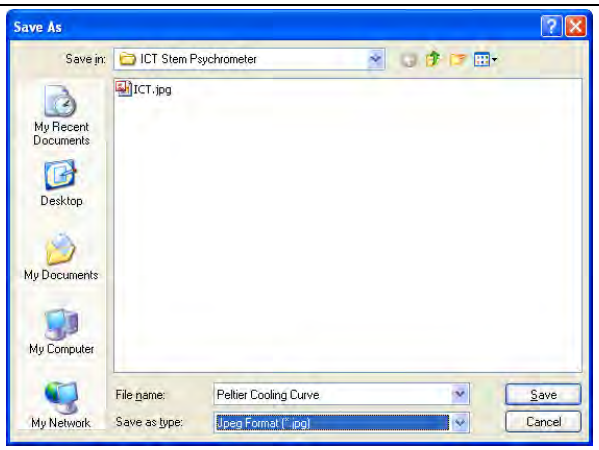


Figure 94 Save As window

20.3.4 Page Setup

Provides access to the printer's "page setup" settings to configure the printer for printing directly to paper.

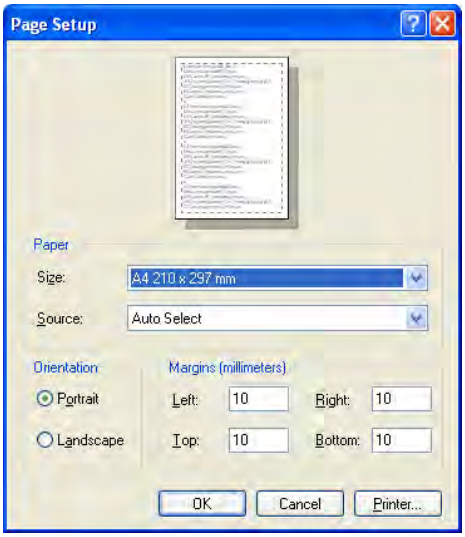


Figure 95 Page setup window

20.3.5 Print

Provides access to the Printer for printing a copy of the graph to paper

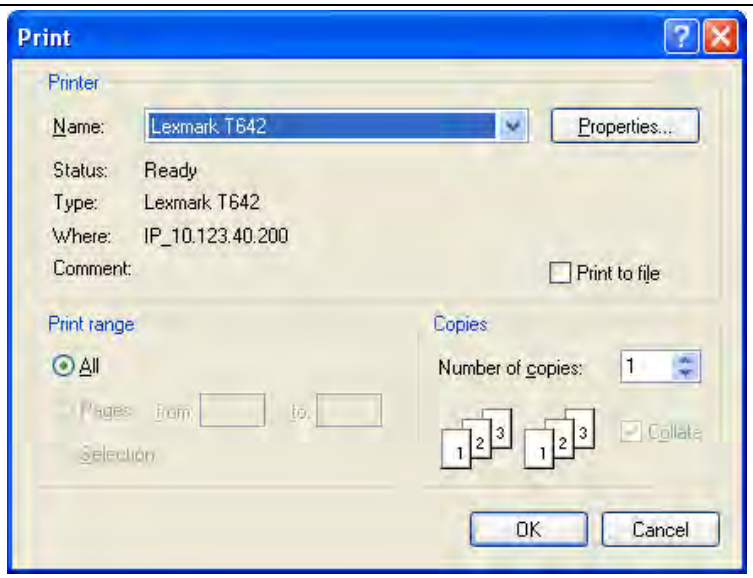


Figure 96 Print window

20.3.6 Show Point Values

The microvolt value for each corresponding time is displayed on the graph for each data point wherever the cursor is held over the line.

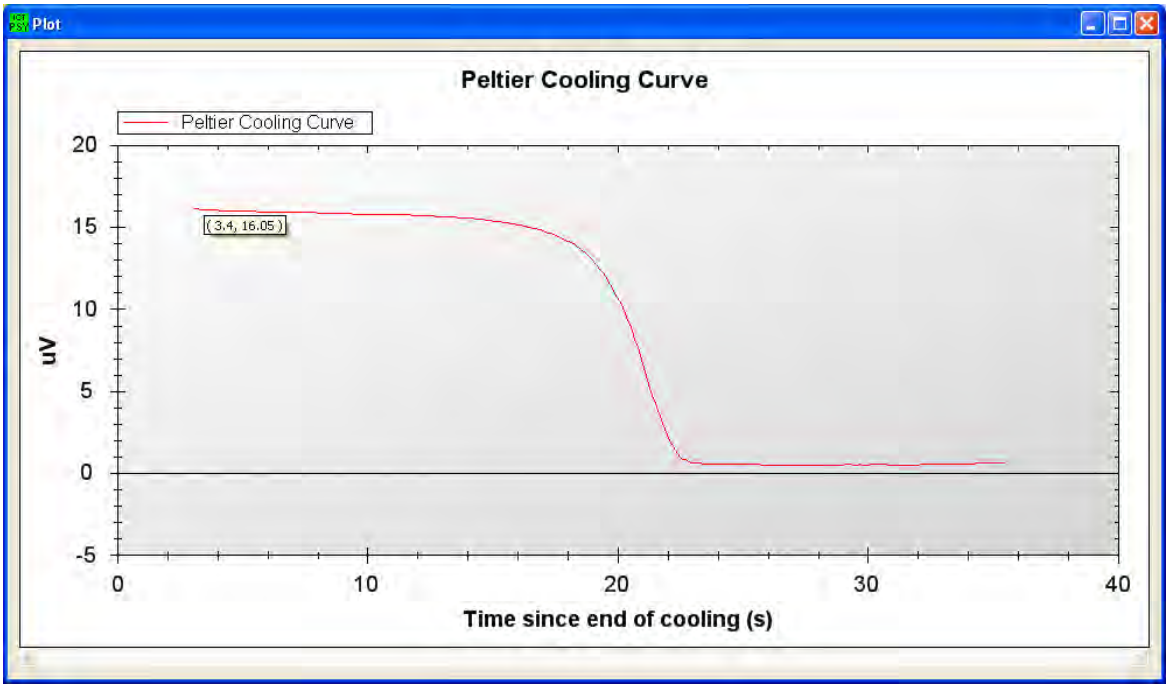


Figure 97 Point values displayed when moving mouse over the line. In this example at 3.4 seconds after the cooling pulse Thermocouple-C output is 16.05 (µV)

20.3.7 Zoom

Specific aspects of the plot can be zoomed in one of two ways.

(a) Select a region of the plot, click & hold the left mouse button and drag to the chosen portion of the plot. The graph will now zoom in on this particular aspect

(b) If you have a mouse with a wheel you can zoom and un-zoom automatically by rolling the wheel forwards and backwards.

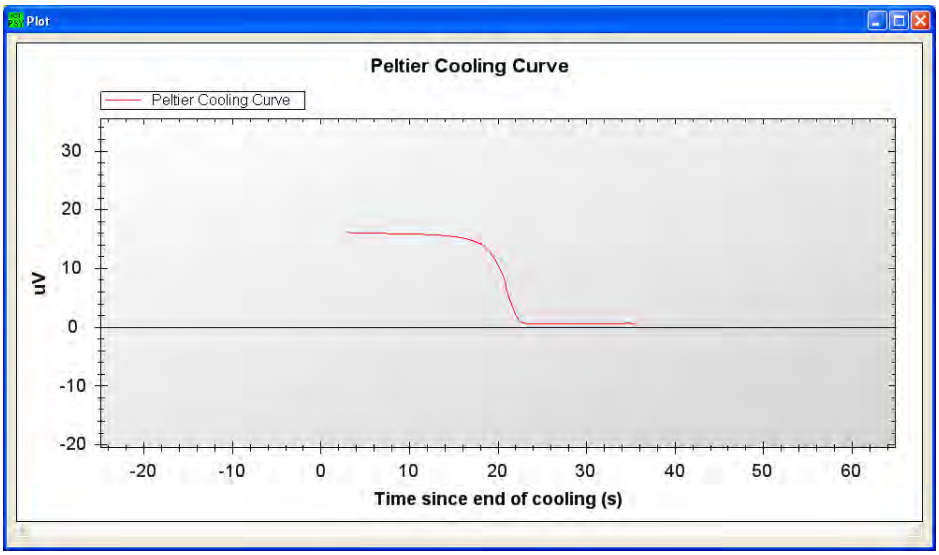


Figure 98 Zoom function on the Peltier Cooling curve plot

20.3.8 Un-Zoom

Provides an incremental reversal of each incremental zoom performed on the graph.

20.3.9 Undo all Zoom/Pan

Provides reversal of all Zoom/Pan's performed on the graph in a single command.

20.3.10 Set to Default Scale

Right click on the graph and select set to default scale and all modifications to the graph scale are discarded and the graph is reset to the original scale.

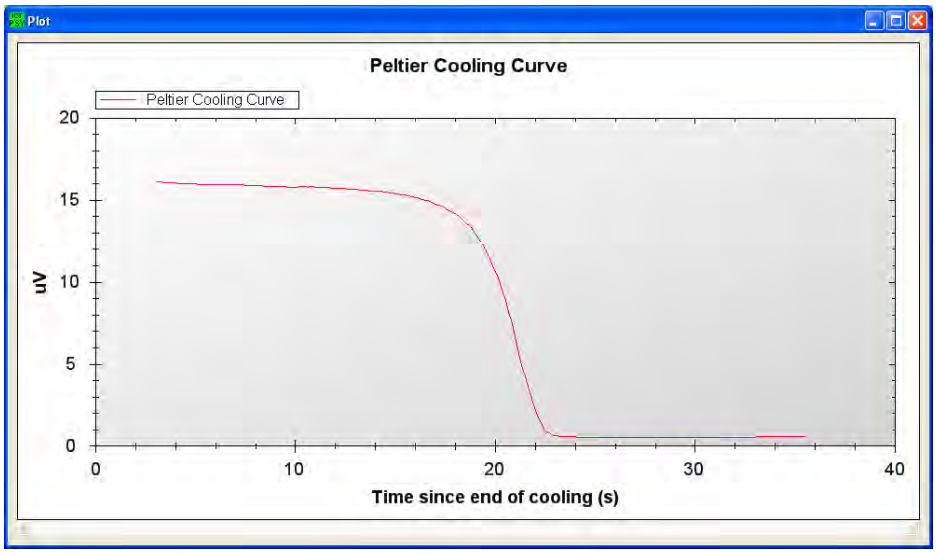


Figure 99 Set to default Auto rescale of Peltier Cooling Curve plot

20.4 Peltier Cooling Curve Raw Data File

The Raw Data File (*_rdf.csv) is a true *.csv file and can be directly opened in Excel. It is a log of the Peltier cooling curve data for each measurement. It is sampled at 10 Hz frequency and it is synchronised with the Main Data file (PSY0A201.csv). It contains an 8 row header line that corresponds to the same header line information of the main data file. This enables direct cross referencing between data files to check the performance or "cleanliness" of the thermocouple against each Corrected Water Potential value recorded. Providing a means of determining if readings are valid throughout the measurement period especially as an installation reaches the end of its productive life.

Serial Number:	PSY0A201	
APP Serial #:	3000008	
Head Serial #:	6	
APP Ver:	R1-4-2	
COM Ver:	R1-3-0G	
Instrument Name:	ICT Demo Stem Psychrometer	
Comment:	Armidale NSW Australia	
Date	**Time**	**Chamber Temperature (°C)**
5/11/2010	19:14:19:0000	20.01
5/11/2010	19:14:19:0100	19.99
5/11/2010	19:14:19:0200	19.97
5/11/2010	19:14:19:0300	19.95
5/11/2010	19:14:19:0400	19.93
5/11/2010	19:14:19:0500	19.91
5/11/2010	19:14:19:0600	19.89
5/11/2010	19:14:19:0700	19.88
5/11/2010	19:14:19:0800	19.85
5/11/2010	19:14:19:0900	19.83
5/11/2010	19:14:20:0000	19.81

Table 2 Raw Data logged data file of the Peltier cooling pulse curve. Used for manual plotting of the Peltier cooling curve.

This data can be manually graphed in spreadsheet software such as Excel to generate the same graph and Peltier cooling curve as the PSY1 software can generate after each manual measurement.

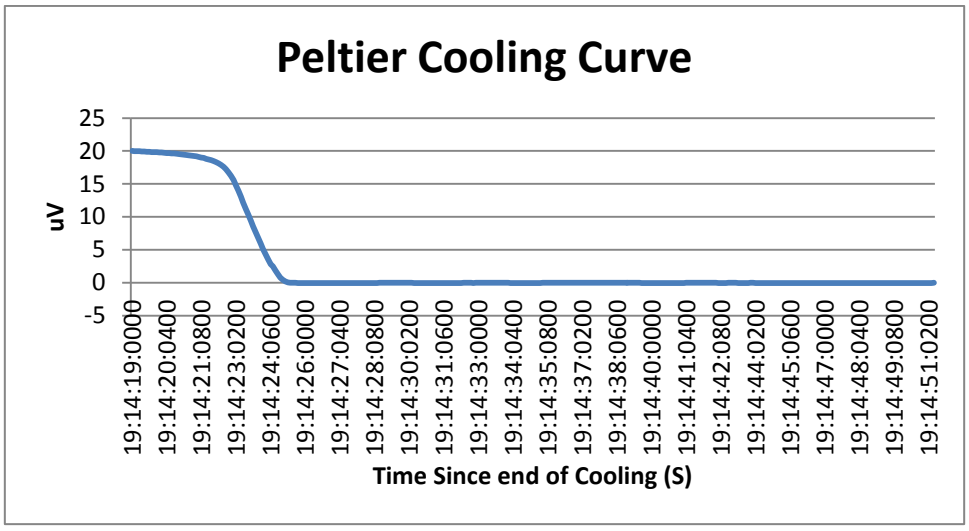


Figure 100 Peltier cooling curve manually graphed in Excel.

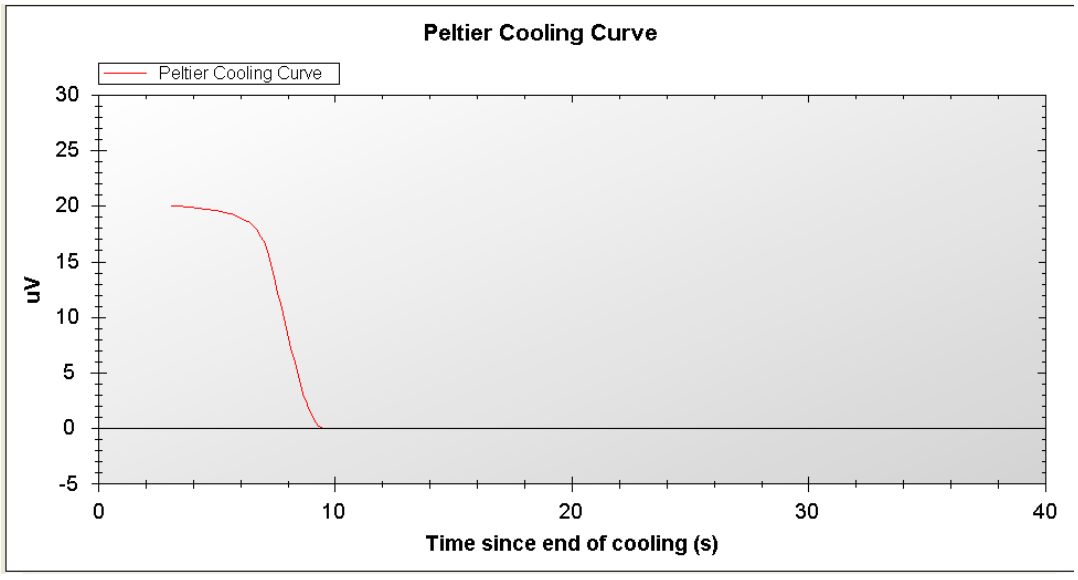


Figure 101. Peltier cooling curve automatically graphed in PSY1 software

21 Data Storage & Downloading

The PSY1 stores three types of data files to the internal MicroSD memory card.

21.1.1 Main Data File

Main data files have a *.csv file extension and are a true Comma Separated Values (CSV) data file that can be easily opened in Excel or SFT software. They are used for logging water potential measurements and associated raw data. These files are typically small in the size range of 10's to 100's KB's

21.1.2 Raw Measurement Data

Raw Measurement Data files have the file extension is *.rdf and are used for logging the high temporal frequency (10 Hz) for the Peltier Cooling Curve data. The file format is actually Comma Separated Values (CSV) file and can be easily opened in Excel or SFT software. These files have the potential to be very large in the range of Mb's to 100's Mb's depending upon the logging interval and longevity of installation.

21.1.3 Live Data

Live data files have the file extension *.lve and are used for logging internal temperature dynamics to assist in the development of chamber heating protocols. The file format is actually Comma Separated Values (CSV) file and can be easily opened in Excel or SFT software. These files are typically small in the size range of 10's to 100's KB's

21.2 SD Card Logging Options

The measurement parameters to be logged can be set on the SD Card Logging Options Window. This is accessed via the PSY Menu. Simply check the box against the data required to be logged.

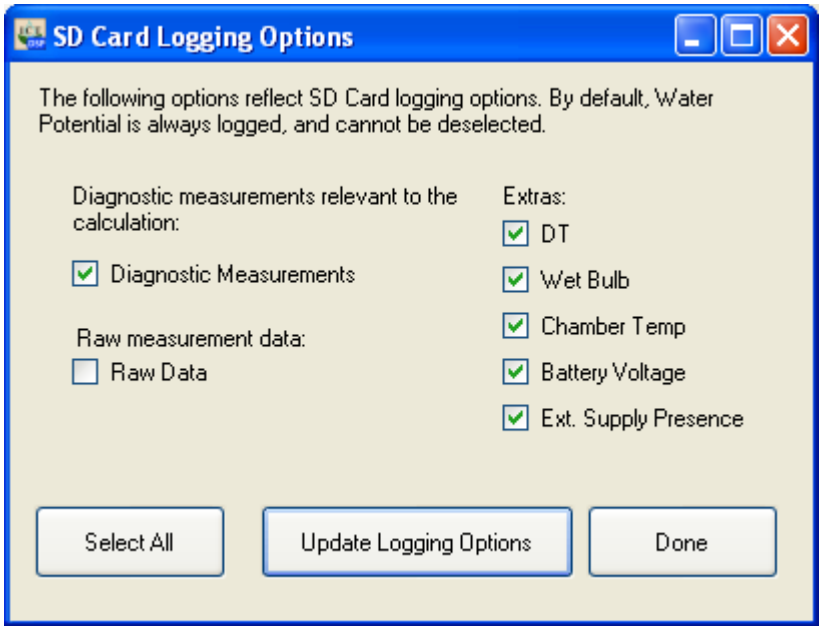


Figure 102 SD Card Logging Options

21.3 Downloading Data

Data is easily downloaded from the Instrument information panel by clicking on the Download Data icon

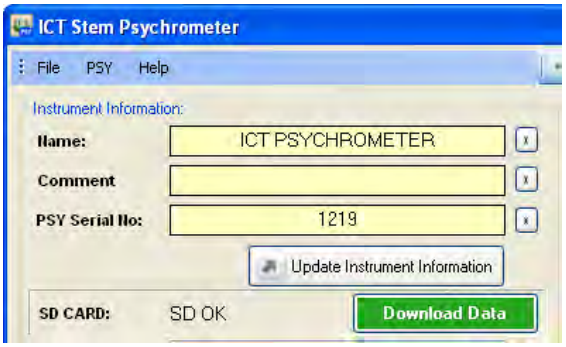


Figure 103 Download Data icon

Clicking this icon immediately brings up the Save As Window to select a directory to save the data to. Once the data is downloaded you are prompted to rename or delete the data file.

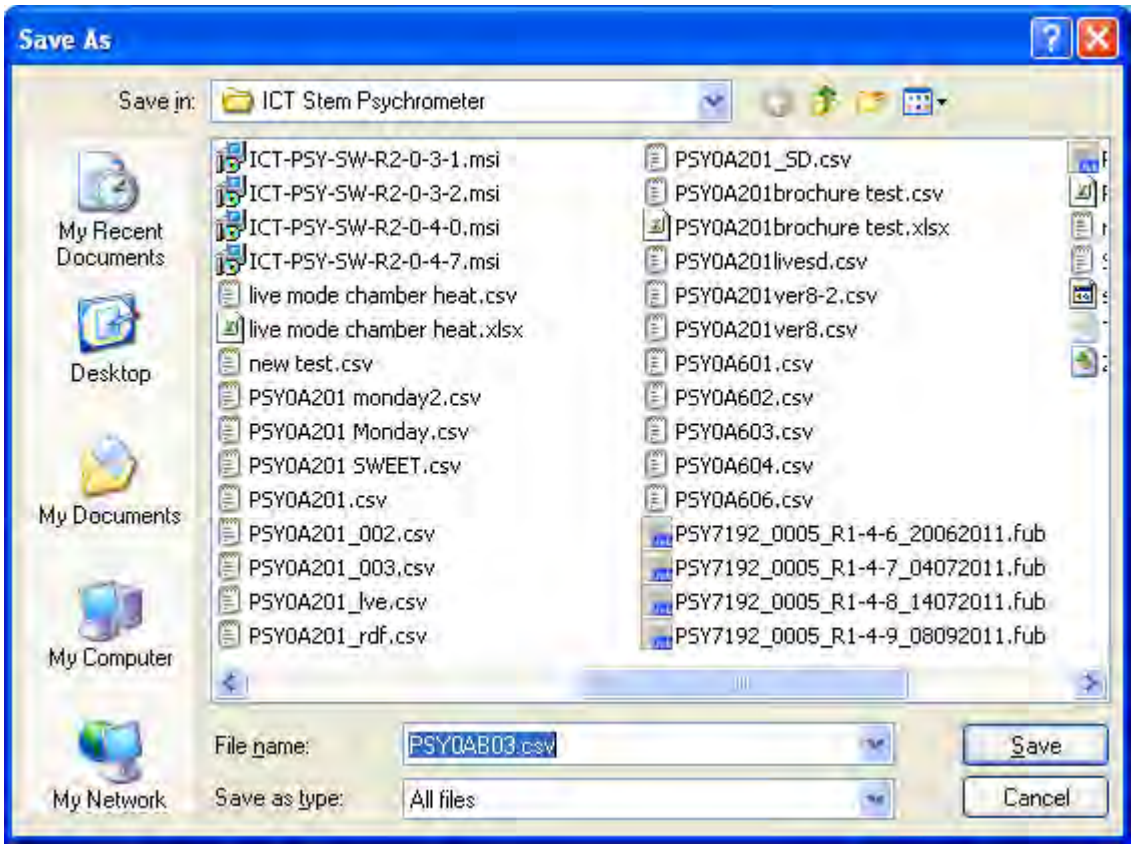


Figure 104 Microsoft Windows Save As window

21.3.1 Via USB Cable

A micro USB cable is supplied for downloading and configuring the instrument. It is a "Standard" cable in most computer stores. The physical USB connection is the simplest method to download data form the PSY1 instrument.

21.4 Via MicroSD card USB Adapter

Alternatively, the PSY1 can be downloaded by removing the Micro SD card and putting it in a USB cradle (supplied by ICT) and inserting to a USB port of a PC. ICT use Microsoft FAT32 formatting so the card is immediately recognizable as a mass storage device when inserted to a PC with Windows OS and files can be dragged and dropped as normal.

The MicroSD card shuttle is a USB port adaptor or card reader. The MicroSD card fits inside the reader so you can plug the MicroSD card directly into a USB port on the PC. The full data transfer speed (seconds for 2GB) is then possible when downloading data. If USB cable is used between the device and the PC then the speed is much slower (minutes).

Photo 41 Micro SD Card Adapter inserted into the USB port of a computer

21.5 Windows FAT-32 compatible.

Data is written to and stored on the MicroSD card in fully compliant Windows File Allocation Table (FAT) format. What this means is that any MicroSD card can be used in the Instrument. There is no limitation that all memory cards must be supplied by ICT. This means any MicroSD card purchased anywhere in the world, or any MicroSD card pulled out of a Digital Camera or mobile phone can be inserted directly into the Instrument for immediate compatibility and use. Similarly any MicroSD card used in the PSY1 can be removed and placed into a Camera, or phone and MOST importantly any Windows PC and is automatically recognised and the data can be copied across through Windows Explorer to any file location on the PC. This means data can be manually downloaded from the instrument by an unskilled or semi-skilled person who removes the MicroSD card from the Instrument and inserts another MicroSD card. The PSY1 automatically generates a new data file and continues logging uninterrupted while the data is returned to the office for download from the MicroSD card.

21.6 Micro SD Card Memory Capacity

The memory capacity of the MicroSD card is 2GB. In practical terms the PSY1 can log all diagnostic measurements relevant to the calculation of water potential and all Extras or fundamental measurement parameters such as dT, Wet Bulb, Chamber temperature, battery voltage and charging current at a 10 minute logging interval for 443 years.

21.7 Renaming data files

When data is downloaded the data file can be renamed (by adding an incremental number to the file extension such as filename.001 instead of filename.csv and the data is then left on the MicroSD card as an “off-site” back up of the master data set stored in the office. This is an inherent data backup and redundancy function.

21.8 Data File Format

The data file is automatically generated using the following format; instrument_serial_number.csv e.g., PSY1A1B2.csv. The serial number not only uniquely identifies each instrument it contains specific information about the date of manufacture and production run. Please provide the serial number to ICT International for all support inquiries.

The PSY1 firmware is Windows FAT-32 compatible. This means that the data storage of the MicroSD card is written in fully complaint Windows File Allocation Table (FAT) format. So any MicroSD card can be used in the Instrument.

As a result the MicroSD cards are “Hot Swappable” meaning it can be removed from the instrument and inserted into a USB port of a Windows PC using a USB card reader or shuttle and then reinserted to the instrument. No closing down, Ejecting or formatting is required.

Note 59 **MicroSD cards can be purchased from any retailer. There is no limitation that memory cards must be supplied by ICT.**

22 Appendices

22.1 PSY1 Test Procedure

(1) Place the PSY-1 in a controlled temperature environment preferably approx 25 ^{o}C . This specific temperature is not essential for testing purposes. The main consideration is a generally stable temperature.

(2) Connect psychrometer chamber to PSY1

(3) Turn on the Instrument

(4) Open PSY1 Software

(5) Find Device

(6) Connect

(7) Change measurement mode from "Manual" to Live Mode and update settings

(8) In "Live Mode" you will see a continuous output of dT, Chamber Temperature and Thermocouple-C this is refreshed at 10Hz sampling frequency

(9) If the connections are ok the results should be as follows:
   a. dT in the range 0 to 1 µV
   b. Chamber Temp, stable and indicative of the ambient conditions (should be within 0.1 °C of actual, but no necessary to test this)
   c. Thermocouple-C: in the range of 0 to 0.8 µV

(10) Run the Instrument in "Live Mode" for approx. 3 minutes continuously. If all values remain stable within the set range the psychrometer, cable connections and instrument are operating well. You can log this data at any interval of your choosing by clicking on the logging interval icon under the Measurement Mode drop down box. This data will be logged automatically to the SD card named "serial number".lve this will serve as a test of the SD card.

(11) Return the unit to Manual mode and perform a measurement. The Peltier cooling pulse should be set to 5 seconds and wait time of 6 seconds as a default in firmware. If not change this in the Measurement protocol tab first.

(12) Use a 1.0 molal NaCl calibration solution on a Whatmans number 1 filter paper punched to the correct size of the well in the calibration lid.

a. An initial measurement is taken of dT and Thermocouple-C.
b. dT should be close to 0 µV (same as for the live test especially if you have not handled the chamber)
c. Thermocouple-C should again be around 0.6 µV and this is used as the electronic Dry Bulb offset (EDBO)
d. Chamber temp should remain the same
e. After the Peltier cooling the Wet Bulb Depression (Thermocouple-C) should reach a maximum value in the range of 19 µV (using the 1.0 Molal solution) and then drop to exactly zero after the measurement.

(13) Click on the Get Latest Data icon then plot the graph of the Peltier cooling curve.

(14) The graph should exhibit the characteristic curve of a plateau of approx. 19 µV commencing on the graph at 4.5 seconds after Peltier cooling finishes. The plateau should last until approx 10 seconds after cooling and then sharply drop to zero. Once back at zero it should remain until the end of the measurement recording period of 40 seconds after the end of Peltier cooling.

Note 60 This long drawn out measurement period is to allow the capture of diagnostics at high water potentials (close to zero) which hold the moisture from the wet bulb depression much longer or dirty thermocouples that slowly drift back to zero or in fact never reach zero.

(15) Repeat 3 manual measurements and verify using the statistics bar in the utility software that the measurements remain stable within (at worst) a few bars from max to min Water potentials. A 1.0 molal solution should return a water potential of -4.64 MPa.

Note 61 allow at least 60 seconds between each of the manual readings as persistent pulsing of the Peltier cooling will add microscopic water to the thermocouple and make the measured water potential less negative (closer to zero MPa). Ideally, 10 minute temporal sampling resolution should be employed but for test purposes 60 seconds is fine as we are just conducting a performance test not an accuracy test.

(16) Again download the data file serial number.csv (this is done automatically by clicking on the Download Data icon) and verify the data was saved.

(17) This completes the functional testing of the PSY.

22.2 Electronic Contact Cleaners

Manufacturer	Product	MSDS	TDS	Picture
CRC	QD Electronic Cleaner	MSDS	TDS	
CRC	XTR Precision Electronic Cleaner	MSDS	TDS	
CRC	CO Contact Cleaner	MSDS	TDS	
Chemtronics	Electro Wash PX	MSDS	TDS	
CRC	NF Contact Cleaner	MSDS	TDS	

22.3 Compressed Air

Manufacturer	Product	MSDS	TDS	Picture
CRC	Air Brush	MSDS	TDS	
Dick Smith Electronics	Air Jet Spray	-	-	

22.4 Preparation of Calibration Solutions

Calibration over a range of water potentials is accomplished using sodium chloride (NaCl) solutions (the molecular weight of sodium chloride = 58.4428 g/mole).

The following Table represents a suitable range of molalities (i.e., mass of salt per unit mass of water) of salt solutions with the corresponding water potential equivalent at 25°C.

You can make these solutions yourself using a sodium chloride, distilled water and carefully measuring the salt & water exactly on a minimum 4 decimal balance. An instructional video is available on the ICT International web site and the CD shipped with this instrument.

Alternatively, premixed calibration solutions can be purchased directly from ICT International or there distributor in your country.

NaCl Molality	**Mass of NaCl (g)**	**Mass of Water (g)**	**Water Potential (MPa)**
0.1	0.2922	50	- 0.462
0.2	0.5844	50	- 0.915
0.3	0.8766	50	-1.368
0.4	1.1688	50	- 1.823
0.5	1.4610	50	- 2.281
1.0	2.9221	50	- 4.640

22.5 Osmotic Coefficients and Water Potentials of Sodium Chloride Solutions

Water Potential (J/Kg)

Molality	0 ^{0}C	5 ^{0}C	10 ^{0}C	15 ^{0}C	20 ^{0}C	25 ^{0}C	30 ^{0}C	35 ^{0}C	40 ^{0}C
0.05	214	218	222	226	230	234	238	242	245
0.1	423	431	439	447	454	462	470	477	485
0.2	836	852	868	884	900	915	930	946	961
0.3	1247	1272	1297	1321	1344	1368	1391	1415	1437
0.4	1658	1693	1727	1759	1791	1823	1855	1886	1917
0.5	2070	2115	2158	2200	2241	2281	2322	2362	2402
0.6	2484	2539	2593	2644	2694	2744	2794	2843	2891
0.7	2901	2967	3030	3091	3151	3210	3270	3328	3385
0.8	3320	3398	3472	3543	3612	3682	3751	3818	3885
0.9	3743	3832	3917	3998	4079	4158	4327	4314	4390
1.0	4169	4270	4366	4459	4550	4640	4729	4815	4001
1.1	4599	4713	4820	4924	5026	5127	5226	5322	5418
1.2	5032	5160	5278	5394	5507	5620	5730	5835	5941
1.3	5470	5611	5742	5869	5994	6119	6239	6354	6471
1.4	5912	6068	6210	6350	6487	6623	6754	6880	7006
1.5	6359	6529	6684	6837	6986	7134	7276	7411	7548
1.6	6811	6996	7163	7330	7491	7652	7805	7950	8007
1.7	7260	7460	7640	7820	8000	8170	8330	8490	8650
1.8	7730	7940	8130	8330	8520	8700	8880	9040	9210
1.9	8190	8430	8630	8840	9040	9240	9430	9600	9780
2.0	8670	8920	9130	9360	9570	9780	9980	10160	10350

1 Bar = 100 J/Kg

Lang, A.R.G, Osmotic Coefficients and Water Potentials of Sodium Chloride Solutions from 0 to 40°C 1967. *Australian Journal of Chemistry*, **20**, 2017-23

22.6 Copper/Constantan Thermocouple Conversion Chart

^{0}C	0	1	2	3	4	5	6	7	8	9	10	^{0}C

MILLIVOLTS

+0	0.000	0.038	0.077	0.116	0.154	0.193	0.232	0.271	0.311	0.350	0.389	+0
10	0.389	0.429	0.468	0.508	0.547	0.587	0.627	0.667	0.707	0.747	0.787	10
20	0.787	0.827	0.808	0.908	0.949	0.990	1.030	1.071	1.112	1.153	1.194	20
30	1.194	1.235	1.277	1.318	1.360	1.401	1.443	1.485	1.526	1.568	1.610	30
40	1.610	1.652	1.694	1.737	1.779	1.821	1.864	1.907	1.949	1.992	2.035	40

22.7 Correction Factors – Ambient Temperature Relationship (MPa/^{0}C)

Note 62 these correction factors are included in Firmware in the PSY1 and are automatically applied based on the measured chamber temperature for each measurement.

^{0}C	+0.0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
10.0	8.755	8.751	8.747	8.743	8.739	8.735	8.731	8.728	8.724	8.720
11.0	8.716	8.712	8.708	8.704	8.700	8.697	8.693	8.689	8.685	8.681
12.0	8.677	8.673	8.670	8.666	8.662	8.658	8.654	8.650	8.646	8.643
13.0	8.639	8.635	8.631	8.627	8.623	8.620	8.616	8.612	8.608	8.604
14.0	8.601	8.597	8.593	8.589	8.585	8.582	8.578	8.574	8.570	8.566
15.0	8.563	8.559	8.555	8.551	8.548	8.544	8.540	8.536	8.533	8.529
16.0	8.525	8.521	8.518	8.514	8.510	8.506	8.503	8.499	8.495	8.491
17.0	8.488	8.484	8.480	8.476	8.473	8.469	8.465	8.462	8.458	8.454
18.0	8.451	8.447	8.443	8.439	8.436	8.432	8.428	8.425	8.421	8.417
19.0	8.414	8.410	8.406	8.403	8.399	8.395	8.392	8.388	8.384	8.381
20.0	8.377	8.373	8.370	8.366	8.362	8.359	8.355	8.352	8.348	8.344
21.0	8.341	8.337	8.333	8.330	8.326	8.323	8.319	8.315	8.312	8.308
22.0	8.305	8.301	8.297	8.294	8.290	8.287	8.283	8.279	8.276	8.272
23.0	8.269	8.265	8.262	8.258	8.254	8.251	8.247	8.244	8.240	8.237
24.0	8.233	8.229	8.226	8.222	8.219	8.215	8.212	8.208	8.205	8.201
25.0	8.198	8.194	8.191	8.187	8.184	8.180	8.176	8.173	8.169	8.166
26.0	8.162	8.159	8.155	8.152	8.148	8.145	8.141	8.138	8.134	8.131
27.0	8.128	8.124	8.121	8.117	8.114	8.110	8.107	8.103	8.100	8.096
28.0	8.093	8.089	8.086	8.082	8.079	8.076	8.072	8.069	8.065	8.062
29.0	8.058	8.055	8.051	8.048	8.045	8.041	8.038	8.034	8.031	8.028
30.0	8.024	8.021	8.017	8.014	8.010	8.007	8.004	8.000	7.997	7.993
31.0	7.990	7.987	7.983	7.890	7.977	7.973	7.970	7.966	7.963	7.960
32.0	7.956	7.953	7.950	7.946	7.943	7.939	7.936	7.933	7.929	7.962
33.0	7.923	7.919	7.916	7.913	7.909	7.906	7.903	7.899	7.896	7.893
34.0	7.889	7.886	7.883	7.879	7.876	7.873	7.869	7.866	7.863	7.860
35.0	7.856	7.853	7.850	7.846	7.843	7.840	7.836	7.833	7.830	7.827
36.0	7.823	7.820	7.817	7.813	7.810	7.807	7.804	7.800	7.797	7.794
37.0	7.791	7.787	7.784	7.781	7.778	7.774	7.771	7.768	7.765	7.761
38.0	7.758	7.755	7.752	7.748	7.745	7.742	7.739	7.735	7.732	7.729
39.0	7.726	7.723	7.719	7.716	7.713	7.710	7.706	7.703	7.700	7.697
40.0	7.694	7.690	7.687	7.684	7.681	7.678	7.675	7.671	7.668	7.665
41.0	7.662	7.659	7.655	7.652	7.649	7.646	7.643	7.640	7.636	7.633
42.0	7.630	7.627	7.624	7.621	7.618	7.614	7.611	7.608	7.605	7.602
43.0	7.599	7.596	7.592	7.589	7.586	7.583	7.580	7.577	7.574	7.570
45.0	7.536	7.533	7.530	7.527	7.524	7.521	7.518	7.515	7.512	7.508

22.8 PSY1 Installation Kit

Object	Overview	Image	Qty
Label Tape	Post insulation the low tack label tape is used to combine the chamber heads.		1
Whatman #1 Filter Paper Discs	Use for calibration procedure and with 1.0 Molal NaCl calibration solution for checking PSY1 operation		20
1.0 Molal NaCl Calibration Solution	A preformulated solution to use in calibration and/or checking of PSY1 operation.		1
Dow Corning Vacuum Grease	Fill the 10 ml Offset Syringe with the grease to create a vacuum seal.		150 gm
Large Clamp Screws	For holding the PSY1 chamber to the large clamp.		X4
Plastic Clip Lock Tool Box	The plastic clip lock tool box protects and stores everything you need for a successful installation.		1

Wash Bottle	Use the wash bottle filled with distilled water to wash off the installation area.		1
Kim Wipes	Use your wipes to make sure the area is completely dry; you may need to rub vigorously.		1
10ml Offset Syringe	Use the syringe filled with Silicon grease to smear around the whole of the wound, thus creating a vapour seal.		1
Polyester Insulation	Use the polyester Insulation to secure the PSY1 Stem Psychrometer after Installation.		1
Single Edge Razor Blades	The razor blade is used to remove bark and excess tissue to create an excessive flat area.		10
ICT Screwdriver	Reversible Philips Head/Flat screwdriver		1

Small Clamp Screws	For holding the PSY1 chamber to the small clamp.		4
Roll of Aluminium Foil	Wrap the foam with aluminium foil to get a radiation shield.		1
Wire Strippers	For Installation of cables		1
Psychrometer User Manual & Software	An Installation disc containing Quick Start Guide, Installation videos, brochures and software.		1
USB Cable	Interface between your computer and the PSY1 Stem Psychrometer.		1
#30 Rubber Bands	For holding the protection cover over the PSY1 chamber to prevent damage to the TS and TC thermocouples.		50
Stainless Steel Tweezers	Use to easily hold and manipulate the filter paper during calibration and checking routines.		1

Micro SD Card Shuttle	The SD Card Reader allows you to transfer your data from the PSY1 to your PC, a quick transfer method.		1

Customer must obtain:

- Distilled water (to go in wash bottle)
- Chloroform
- Compressed Air (moisture free)

22.9 Support Log

Please fill in the information below to assist in troubleshooting

Customer Name:
Customer Comment:

PSY Support Log Started: 30/07/2012 3:26:21 PM
PSY.Ver: 2.0.4.8
INS.Name: ICT PSYCHROMETER
INS.Comment: 24/JUL/2012 9:19 11pF
PSY.Ser#: 1234
APP.Ser#: 55FF3FCD
GCB.Ser#: 010008BC
UNT.Ser#: PSYTC705
APP.Ver#: R1-5-2
GCB.Ver#: R2-2-9
DC: Device Date: 30/07/2012 Device Time (24hr): 15:26
AU.EN: True
AU.START: True
AU.Date:
AU.Avail: False,False
AU.Valid: False,False
SDC: SD OK
BATT.Volt: 4.22 V
BATT.Stat: idle
MEAS.Mode: Manual
MEAS.LiveInterval: Live Mode Logging Interval:
MEAS.Sch: 99999
MEAS.Status: Measurement Stopped
MEAS.Next: 00:00 False
MPROT.CalSN: PSYTC705
MPROT.CalCmnt:
Slope: -1.16
Intercept: 1.28
MPROT.CT: 10 s
MPROT.WT: 6 s
MPROT.PWD: Disabled
MPORT.PWW: 15s
MPROT.CHD: Disabled
MPROT.CHS: 1/01/2000 12:00:00 AM-1/01/2000 12:00:00 AM,True
Logging Options:
DT
WB
Chamber Temp
Correction Factors
Battery Voltage
External Supply Presence
OS: Microsoft Windows NT 6.1.7601 Service Pack 1
Runtime: 2.0.50727.5456
Processor Count: 4
PSY Support Log Complete: 30/07/2012 3:26:21 PM

22.10 Debug File

Computer Information:

ACPI:
DeviceID: ACPI\GENUINEINTEL_-_X86_FAMILY_6_MODEL_28_0, Name: Intel(R) Atom(TM) CPU N270 @ 1.60GHz
DeviceID: ACPI\GENUINEINTEL_-_X86_FAMILY_6_MODEL_28_1, Name: Intel(R) Atom(TM) CPU N270 @ 1.60GHz

DeviceID: ACPI\PNP0C0C\2&DABA3FF&0, Name: ACPI Power Button
DeviceID: ACPI\PNP0C0D\2&DABA3FF&0, Name: ACPI Lid
DeviceID: ACPI\PNP0C0E\2&DABA3FF&0, Name: ACPI Sleep Button
DeviceID: ACPI\PNP0C0A\0, Name: Microsoft ACPI-Compliant Control Method Battery
DeviceID: ACPI\ACPI0003\2&DABA3FF&0, Name: Microsoft AC Adapter
DeviceID: ACPI\PNP0A08\2&DABA3FF&0, Name: PCI bus
DeviceID: ACPI\PNP0C02\4&38462492&0, Name: Motherboard resources
DeviceID: ACPI\PNP0200\4&38462492&0, Name: Direct memory access controller
DeviceID: ACPI\PNP0B00\4&38462492&0, Name: System CMOS/real time clock
DeviceID: ACPI\PNP0103\4&38462492&0, Name: High precision event timer
DeviceID: ACPI\PNP0000\4&38462492&0, Name: Programmable interrupt controller
DeviceID: ACPI\PNP0C04\4&38462492&0, Name: Numeric data processor
DeviceID: ACPI\PNP0100\4&38462492&0, Name: System timer
DeviceID: ACPI\INT0800\4&38462492&0, Name: Intel(R) 82802 Firmware Hub Device
DeviceID: ACPI\PNP0303\4&38462492&0, Name: Standard 101/102-Key or Microsoft Natural PS/2 Keyboard
DeviceID: ACPI\PNP0F13\4&38462492&0, Name: Synaptics PS/2 Port Pointing Device
DeviceID: ACPI\PNP0C09\4&38462492&0, Name: Microsoft ACPI-Compliant Embedded Controller
DeviceID: ACPI\PNP0C14\0, Name: Microsoft Windows Management Interface for ACPI
DeviceID: ACPI\FIXEDBUTTON\2&DABA3FF&0, Name: ACPI Fixed Feature Button

USB (All):
DeviceID: USB\ROOT_HUB\4&FCF8232&0, Name: USB Root Hub
DeviceID: USB\VID_046D&PID_C03D\5&C6F674&0&1, Name: USB Human Interface Device
DeviceID: USB\VID_0403&PID_6001\A8004QQR, Name: USB Serial Converter
DeviceID: USB\ROOT_HUB\4&2EEF2415&0, Name: USB Root Hub
DeviceID: USB\ROOT_HUB\4&1BAA685&0, Name: USB Root Hub
DeviceID: USB\ROOT_HUB\4&4DE82C5&0, Name: USB Root Hub
DeviceID: USB\ROOT_HUB20\4&624C0C7&0, Name: USB Root Hub
DeviceID: USB\VID_0C45&PID_62C0\5&1ECD3563&0&5, Name: Acer Crystal Eye Webcam
DeviceID: ROOT\USB\0000, Name: Nokia Internet Stick DC Control

USB (ICT):
DeviceID: USB\VID_0403&PID_6001\A8004QQR, Name: USB Serial Converter

FTDIBUS :
DeviceID: FTDIBUS\VID_0403+PID_6001+A8004QQRA\0000, Name: USB Serial Port (COM25)

Connecting to ICT PSY on COM25
Message timeout: MSG_SSERIAL
Message timeout: MSG_SSERIAL

Message timeout: MSG_SSERIAL
Message timeout: MSG_SSERIAL
Message timeout: MSG_SSERIAL
Message timeout: MSG_SSERIAL
Message timeout: MSG_SSERIAL
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Message timeout: MSG_SSERIAL

22.11 Extension Cable Specs

As the PSY1 is powered from its internal battery with a non-polarised charging circuit no special power cables are required. A simple 2-core “Figure-8 cable” or “Lamp Cord” of following specifications is ideal:
Size: 2 x 24/0.20
Voltage Rating: 300V AC
Current Rating: 7.5 Amps
Dimensions: 2.6 x 5.1mm
Conductor Area: 0.75mm2
Conductor Gauge: 18AWG
Temperature Rating: 90°C
Roll Size: 30m

22.12 SD Card Re-Initialisation

SD Card Initialisation procedure check:

- Initialise SD Card
- Check SD Card Communication / Initialisation
    - If ok, check whether the file system is of correct format
        - If ok, check serial number to see if a valid CSV file can be created
            - If ok, set SD Card status to SD OK
            - If fail, set SD Card status to FILENAME ERROR
        - If fail, set SD Card status to WRONG FORMAT
    - If fail, set SD Card status to SD ERROR

23 Contact Details

ICT International Pty Ltd
Solutions for soil, plant & environmental monitoring

www.ictinternational.com
sales@ictinternational.com.au
Phone: +61 2 6772 6770
Fax: +61 2 6772 7616
PO Box 503, Armidale, NSW, Australia, 2350